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A Journal of Neurology

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Original Articles and Clinical Cases.

REMARKS ON THE REFLEX MECHANISM OF THE STEP.[1]

BY C. S. SHERRINGTON, M.D., F.R.S.

To an observer who would analyse them, the acts of walking, running, and of progression in its various forms present themselves in every case as actions compounded of a posture and a movement. In such acts we see particularly clearly exemplified a twofold activity of the nervous system. An activity which uses the musculature to maintain static effects — postures, and an activity which uses it to produce kinetic effects—movements. Thus, the static component in walking is maintenance of the erect posture; the kinetic component is a rhythmic alternating movement of the limbs—stepping. This static component is closely related to that which constitutes standing, so closely, in fact, that such acts as walking and running may for analysis be conveniently regarded as the postural act of standing upon which there are grafted rhythmic flexion-extension movements of each limb in turn, resulting in locomotion.

In their importance to the existence of the individual and the species the acts of standing and progression seem, among all the work of the striped muscles, to rank second only to that of respiratory ventilation of the lung, and the actual prehension of food by the mouth. Their prime importance and their inherent, though in man post-natal, development suggest that in essence the organization of these acts must, even in man, be purely reflex. The belief is, indeed, general that such an act as walking, when stripped of extraneous regulative influences which can start, restrain, modify, and adjust it to varied circumstances, has at basis a fundamental mechanism of purely reflex operation.

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[1] Presidential Address to the Neurological Section of the Royal Society of Medicine.

That the act of walking is not dependent on the integrity of the cerebral cortex has long been proved experimentally by well-known experiments on the lower vertebrates, and on mammals even of such high type as the dog. In the dog Goltz removed both cerebral hemispheres to such an extent that only the basal part of the two temporal lobes remained, and these remnants, with the corpora striata and parts of the optic thalami and anterior colliculi, were in a condition of detritus and softening when the autopsy was made. This dog was yet able to walk, and did, indeed, walk "spontaneously."

It seems clear that inquiry regarding the mechanism executive of such an act as reflex walking must include search for a postural reflex which will also underlie the act of standing, and for a purely reflex limb-movement which will be the essential reflex of the step.

As to the former of these, the postural reflex, experimental search meets with a positive result as follows. When all of the brain in front of a transection between anterior and posterior colliculi is removed in a cat or dog, the decerebrate preparation thus obtained exhibits a systemic postural reflex with the following features. The extensor muscles of all four limbs, the dorsal muscles of the back, neck, and tail, the retractors of the head, and the elevators of the lower jaw, are all in harmoniously co-ordinated steady tonic contraction. This contraction is reflex, for it is at once abolished in each local region by severance of the afferent spinal roots of that region; for instance, in a limb by severance of the afferent spinal roots of that limb, in the neck by severance of the afferent roots of the neck, and so on. So local is its reflex origin that in the extensor muscle of the knee, for instance, it is *essentially* dependent on the afferent nerve of that muscle, and on no other afferent nerve: it can be increased through other afferent channels, but is not essentially dependent on them. In this tonic reflex, though all the above-mentioned groups of muscles—they may briefly be termed extensors—exhibit the tonic contraction, their antagonists do not exhibit contraction. On the contrary, they appear to lie under a tonic reflex inhibition, which keeps them in a state of slight relaxation, the converse of the mild, persistent contraction of the extensors. This widespread tonic reflex which constitutes decerebrate rigidity does not draw its source from skin-afferents; its origin is traceable to the deep afferents, especially those belonging to the extensor muscles themselves, exhibiting the reflex tonus. The postural reflex is, in fact, a proprioceptive reflex.

The muscles exhibiting the steady contraction executing this general reflex, although they are widely distributed in the body, compose nevertheless a homogeneous system. They all by their contraction contribute to one common result. They each and all, by contracting, counteract gravity in the ordinary erect position usual to the animal, the *usustatus*.[1]

In the limbs they keep the limb from yielding under its own weight and under that of the body superimposed. In neck and head they keep those parts from falling; similarly in the tail they keep it from dropping, and in the head they keep the lower jaw in apposition to the upper, so that the mouth is closed. In fact, their reflex tonus is, as I have pointed out elsewhere [7], simply the expression of a maintained posture.[2] If the preparation be passively set upright on its feet the systemic tonic reflex ~~suffices to~~ support it in the erect posture. In short, the postural reflex is "standing" executed purely reflexly. The decerebrate preparation maintains its "standing" attitude even for hours at a time.

The decerebrate preparation possesses the otic labyrinths and nervi octavi. It might be thought that these great receptors and their afferent apparatus were responsible for the standing reflex which the preparation exhibits. The beautiful researches of Ewald have shown the widely distributed tonic influences which these organs can exert. But the decerebrate preparation still continues to stand when the otic labyrinths have been destroyed or the octavi cut. This is so both when the labyrinths are removed or octavi severed subsequent to decerebration and appearance of the static postural reflex, and also when the labyrinths have been destroyed or octavi cut a short time prior to the decerebration. In the latter case my observations, in several of which I have to thank Dr. S. Sewell for invaluable co-operation, have at present dealt with decerebration practised at a short interval only after ablation of the labyrinths. The longest periods were in one case decerebration four days after removal of both labyrinths, and in another eight days after removal of left labyrinth and two days after removal of the right. These lesions did not prevent the full postural reflex from ensuing on decerebration, nor did they even impair it noticeably. Reflex standing still engaged the preparation. These results, so far as they go, agree with the further fact that the decerebrate preparation still continues to exhibit the postural reflex of "standing" when laid on its side or even when inverted. In this latter

[1] This convenient term was first introduced by Karl Schaeffer [6].

[2] *Cf.* also Lewandowsky [5].

position, however, the reflex posture is not usually, in my experience, maintained for long. That the otic labyrinths can *influence* the postural reflex of the decerebrate preparation is undeniable, but, so far as my observations at present go, they are not responsible for the fundamental execution of the reflex. The reflex can occur without them.

A feature of the reflex tonus which thus executes the posture of standing in the decerebrate preparation is "plasticity." The length of this or that muscle or muscle-group is capable of modification without detriment to or disturbance of the tonic tension of the muscle. Each such local modification is given by an intrinsic proprioceptive reflex. The plasticity appears to meet the requirement that in "standing" the posture of the limb may vary, provided always that each joint maintains a resistance sufficient to counteract the tendency of the superimposed weight it carries to flex it. Ordinary standing postures, especially in the quadruped, include variable degrees of flexion at hip and knee, and the pose of extension is usually greater at the knee. One hind-foot may rest close beside the other or in advance of or behind it. Yet in all cases, though the tonic length of the muscle varies greatly, its tonic tension varies little and does not fall below that required to bear the superincumbent load. In this postural reflex the extensor muscles are, to follow v. Uexküll's terminology, acting as "Sperr-muskeln." Thus in each limb they secure that, in the various positions of the joints in standing, the tension of the muscles shall still continue adjusted to the support the limb requires in the standing animal. Just as the sea-urchin rests supported on its spines by the "Sperrreflex" of the tonic muscles of the spines, so the decerebrate cat and dog stand in virtue of the "Sperrreflex" stiffening the jointed framework of the animal by means of the tonus of the anti-gravity muscles.

This reflex standing disappears when the transection of the brain is made behind the posterior edge of the pons. It is not present, therefore, in the decapitated preparation; the decapitated preparation cannot, so far as I have seen, stand. To decide how far this abolition of the reflex standing is a matter of shock, or how far with lapse of time the ability to stand is recovered, recourse must be had to other preparations than the decapitated. When in the dog the spinal cord is severed in the thoracic region the hind-limbs cannot at first stand; but after lapse of weeks or months they exhibit this power. That is, with hind-feet on the ground the reflex tonus of limb-extension suffices to bear the weight of the limbs and superincumbent hind-quarters. The attitude thus exhibited indubitably amounts to standing and is sometimes maintained for minutes at a time. But this spinal standing is not fully equivalent to the standing of the decerebrate preparation. It is less steady, is subject to sudden lapses, irregular in intensity, less enduring, and allows less latitude of variation in the exact posture of the limbs. The tonus which executes it is less plastic. Sometimes it cannot be obtained at all. The tonic contraction which executes it is, however, like that of the decerebrate preparation, independent of the cutaneous afferents. It is like that of the decerebrate preparation, a reflex of proprio-ceptive nature.

Experimental search for the postural or static component of walking, considered as a purely reflex act, arrives therefore at a definite result. It finds a tonic postural reflex able to execute the *usustatus* after removal of the whole fore-brain and part of the mid-brain as well. And it finds that a residuum of that reflex *usustatus* is obtainable even as a purely spinal reflex.

Turning now to the other component of walking—the kinetic—responsible for the movements of the step, and looking for a purely reflex reaction as its basis, we may again take as our field the hind-limb, especially since data from it are more immediately applicable to the bipedal progression of man The hind-limbs of the dog, when the period of shock has passed, after thoracic spinal transection exhibit a rhythmic movement, the similarity of which to stepping was noted by its first investigators, Goltz and Freusberg. Recently the kinematograph analysis of these movements by Philippson has convincingly established their identity with normal stepping.

Similar reflex stepping can also be observed with facility in the decapitated preparation (cat). If the lungs of the carcase of a decapitated cat be appropriately ventilated by bellows, the headless preparation will continue for several hours to exhibit, under appropriate stimuli, various reflexes. A significant feature of such spinal reflexes is that they tend to be of *alternating* form, thus in the limbs their movements exhibit alternating flexion and extension; flexion tends to be followed by extension, this again by flexion, and so on alternately. Among these *alternating reflexes* that of stepping, especially of the hind-limbs, is prominent. An effective stimulus for exciting the stepping movement is pressure by a small spring clip applied to the skin. Certain skin regions provoke the reflex best: for instance, that of perineum or of a foot, but not that of the limb which is to step. The stimulus is continuous and constant, but the reflex response of the musculature engaged in the stepping is rhythmic. Faradization of an afferent nerve will also evoke the reflex stepping. Here the stimulus, though it is essentially rhythmic, has a rate of rhythm far faster—about 30 per second— than that of the rhythmic movement—about 2 per second—which it evokes. The reflex stepping may be also produced by direct faradization of the cross-section of the lower end of the bulb or top of the spinal cord laid bare by the decapitation. This faradization evokes stepping in the hind-limb of that half of the cord to which the electrode (unipolar) is applied; and the ipsilateral stepping is often accompanied by weaker stepping of the contralateral hind-limb.

It appears clear, therefore, that the rhythmic response of the musculature is referable to a rhythm not resident in the stimulus or in sense-organs of the skin, but developed in the spinal centres occupied with the reflex action. In other words, in these centres there arises a rythmically recurrent refractory phase. Thus faradization of the cross-section of bulb or cord excites in the hind-limb of the same side a stepping movement which opens with limb-flexion; this flexion is succeeded a fraction of a second later by extension, this extension a fraction of a second late by flexion, and the flexion again by extension, and so on. In other words, the stimulus which primarily causes contraction of flexor muscles fails to do so a fraction of a second later, and then a fraction of a second later succeeds in exciting them again, and then again fails, and so on. The development of a refractory phase in reflex reactions is coming to be recognized as of common occurrence. The scratch-reflex, affecting as it does the same hind-limb muscles as does the reflex step, similarly exhibits a closely comparable refractory phase. In the scratch-reflex the tempo of the scratch-movement, *i.e.*, the rate of recurrence of the refractory phase, is little affected by alteration of the intensity of the stimulus. But in the stepping reflex, increase of the intensity of the stimulus increases the tempo of the step. This is equivalent to saying that intensifying the stimulus does not lead to prolongation of the excitatory effect; it brings increased intensity of discharge followed by acceleration of the onset of the refractory phase, and the refractory phase itself is of shorter duration.

The origin and intimate nature of the refractory phase is obscure. It is a phenomenon which seems akin in many ways to inhibition. Verworn and Fröhlich regard it as a relative exhaustion, a kind of fatigue. The well-known refractory phase of the heart during which the myocardium becomes irresponsive or incompletely responsive to stimulation naturally rises to mind as a possible type for a refractory phase in general. There is some evidence referring refractory phase in the heart to the liberation of potassium-ions present with sodium- and calcium-ions in the tissue.

And from the work of Macallum and of Macdonald we know the richness of the neuron in potassium and the intimate connexion between the liberation of this salt and functional activity. There is some evidence that the inhibitory action of the vagus on the heart is due to the liberation by that nerve of potassium from compounds that bind it in that part of the heart whence the beat originates. In the spinal reflexes under consideration the refractory phase is further complicated by the circumstance that these reflexes, step-reflex and scratch-reflex, are not only rhythmic but alternating. Thus, when the stimulus becomes ineffective for the flexor moto-neurons it becomes effective for the extensor moto-neurons, and conversely.

The stimuli above mentioned which excite stepping are all of them "*remote*"—that is, their place of application lies not within but outside the limits of the stepping limb itself. The stepping movement can, however, be excited by stimulation directly incident on the limb itself, though not by stimulation of its skin. Here the agent of stimulation has to be in the form of movement—for instance, passive movement of the limb. Perhaps posture also is effective. When the dog with spinal hind-limbs is lifted from the ground so that those limbs droop pendant, the hanging limbs at once begin to step. If, then, one of them be gently supported from beneath so that the hip is flexed, the reflex stepping subsides in it at once, and usually in the other limb as well, although that limb is quite free. On removing the support and letting the limb drop under its own weight once more, the passive extension so produced at once provokes active flexion at the crossed hip, and is followed in the limb dropped, after fair extension has occurred, by active flexion at the hip, the knee, and the ankle, accompanied in the fellow-limb by active extension at the similar joints. The stimulus exciting this reaction is the passive extension, chiefly of the hip. This reaction occurs just as well when all the skin-afferents of the limb are severed. The passive movement acts as a proprio-ceptive stimulus, and the reflex stepping as thus evoked is entirely a *proprio-ceptive reflex*.

An experiment of interest in this connexion is the following: The sartorius muscle (cat, dog) consists of two parts which form two parallel bands. Of these bands the median passes to tibia, and is a flexor of the knee as well as a flexor of the hip. The other passes to the patella, and is a flexor of the hip, but also an extensor of the knee, especially in its lower part. The sartorius can be separated from its insertions and its lateral and deep attachments without impairing its nerve or blood-supply. When this has been done it can be seen that in the decapitated preparation passive full extension of the knee provokes reflex contraction of the median band of sartorius and in part of the lateral band; passive full flexion of the knee provokes reflex contraction of the lateral band of sartorius and, to a less extent, in the median band. Passive extension of the limb excites reflex contraction of a flexor of the limb, passive flexion of the limb excites reflex contraction of an extensor of the limb. But of the two effects, the former is the more marked and regular in the decapitated preparation. This applies also to other flexor muscles. Thus passive extension of the knee and the ankle, and of the knee alone, excites reflex contraction in the semitendinosus and biceps femoris posterior—both of them flexors of the knee. But the same passive extension does not excite contraction in the semimembranosus or biceps femoris anterior, extensors of the hip and indirectly of the knee.

Such results are evidently akin to the phenomenon of *reversal*, the observation of which we owe to J. v. Uexküll and R. Magnus. This *reversal* consists in a reversal of the direction of a reflex movement brought about by reversing the initial posture of the joint or joints affected by the reflex. Thus, in the ray-arm of the brittle-star (v. Uexküll) and in the tail of the spinal cat (Magnus) the stimulus which, when the initial pose of the appendage is to the left deflects it to right, deflects it to left when the initial pose is to the right. Magnus has shown that a similar influence is traceable in the spinal reflexes of the dog's hind-limbs. From such "reversal" influence it seems only a step further when, as in the above experiments, a passive extending of the knee excites, towards its completion, a reflex contraction of the knee-flexors.

But in my experience, so far as it goes, movements of a purely passive kind do not excite reflex movement of opposite direction to their own with that readiness which might be expected were they of themselves alone wholly competent to give the alternations exhibited by such reactions as the step-reflex and the scratch-reflex. It would seem that additional factors must co-operate in the production of these alternations. And these additional factors may be present in active movements, though wanting in movements merely passive. In the active movement not only are the muscles antagonistic to the movement lengthened passively by the mechanical pull of the movement, but they are relaxed by central inhibition of their excitation of whatever grade that may be at the time. And in addition their protagonists, the prime movers, as Charles Beevor, whose loss is still so fresh a grief with us, termed them, are shortened and tightened and subjected to electrical disturbance—in short, become seats of change they do not experience in merely passive movement.

Active movements appear competent, therefore, to originate proprioceptive stimuli more potently than passive movements. And Goldscheider found their threshold of perceptibility lower, though not greatly lower, than that for passive movements. If they are more potent exciters of sense they may be expected to be more potent exciters of reflex action. And, further, an active movement predicates active changes excitatory, and inhibitory, in the spinal centres themselves, and of a kind and in a measure wanting to purely passive movements. In these active *central* changes, excitatory and inhibitory, seems to lie an important predisposing condition for further changes determining subsequent reflex events.

To consider these it is necessary to revert for a moment to the actual distribution of the reflex effect upon the limb-musculature observable in each of the two phases which compose the limb-movement of the reflex step. The step is a diphasic movement. There is a flexion phase in which the limb, its weight being carried as Weber showed by the atmospheric pressure on the hip-joint, is drawn forward by flexion at the hip, and is lifted clear of the ground by flexion of the knee and ankle during the earlier two-thirds of the phase. On the flexor phase follows the extensor phase. In this phase the hip, knee, and ankle are simultaneously extended, and the straightening limb propels the body forward at the same time supporting its weight.

In this diphasic movement the protagonists of one phase are the antagonists of the other. Thus such a muscle as the vastocrureus is a protagonist in the extensor phase, and as such exhibits excitation during that phase. But in the flexion phase, where for instance the sartorius is a protagonist, the vastocrureus is an antagonist, and as such exhibits inhibitory relaxation. In each of the two opposed phases certain motor neuron-groups are being excited, and certain concurrently depressed by inhibition. And the groups depressed by inhibition are the antagonists of the groups which are excited. Thus, the extension phase of the step is brought about by excitation of the extensor centres of the limb with concurrent inhibition of the flexor centres; and the flexion phase of the step is brought about by excitation of the flexor centres and concurrent inhibition of the extensor centres. Now a common phenomenon when reflex flexion of the limb is produced in the spinal, and especially in the decerebrate, preparation, is that on withdrawal of the stimulus producing the flexion, not merely does the flexion lapse, but it is followed by an active extension. This *rebound* extension appears due to a post-inhibitory exaltation of activity in the previously inhibited extensor centres. Conversely a rebound flexion often ensues on withdrawal of a stimulus excitatory of extension. These rebound discharges are akin to a phenomenon which Head [3] noted in his work on the regulation of the respiratory movements. Head stimulated the central end of one vagus with faradic currents just too weak to produce a complete reflex tetanus of the diaphragm. During this condition an inflation of the lung at once produced relaxation of the diaphragm by reflex inhibition. When the lungs had returned to their normal volume after the inflation, the stimulus previously inefficient to produce complete tetanus of the diaphragm became at once efficient. A period

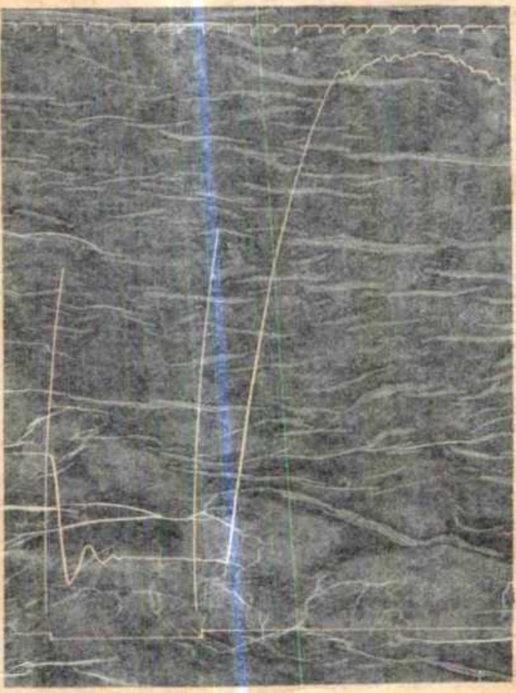

FIG. 1.

Post-inhibitory exaltation. The tracing is from the knee-extensor, *vastocrureus*. The muscle is at the outset of the tracing exhibiting tonic contraction, for it is taking part in the postural reflex of standing which involves maintained extension of knee. A stimulus is then applied (*see* notch in signal line below) appropriate for producing knee-flexion. The vastocrureus is immediately relaxed (descent of myograph line) by reflex inhibition, and remains relaxed so long as the stimulus continues. The stimulus is then withdrawn and the muscle re-exhibits contraction (rebound contraction), and this contraction is greatly in excess of the grade of the contraction it exhibited prior to the reflex inhibition. Time in quarter seconds above.

of inhibitory depression is followed by a period of increased responsiveness to excitation. Similarly, with the spinal limb-centres a stimulus evoking only a slight reflex extension of the limb will, when applied soon after the occurrence of a strong flexor reflex of the limb, evoke a much more ample and long-lasting reflex extension than

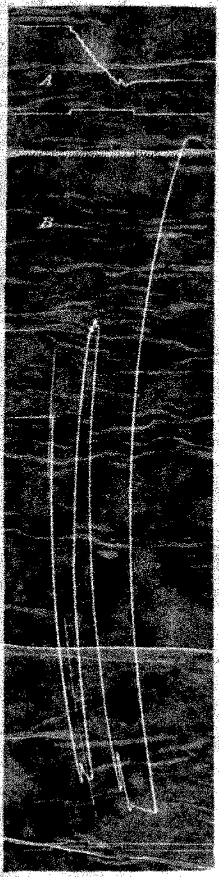

Fig. 2.

Post-inhibitory exaltation. Tracing from the knee-extensor, *vastocrureus.* A, exhibits the weak reflex inhibition caused by a weak stimulus. B, powerful reflex inhibition caused by a much stronger but otherwise similar stimulus. This stimulus for the period shown by the rise in the upper signal line in the lower tracing was abruptly weakened to the lesser intensity it had in A. The muscle under this change at once reverts to contraction not merely of the grade that it had before the inhibition, but to a higher grade of contraction than that. Post-inhibitory exaltation has so heightened the activity of the reflex centre that a rebound contraction occurs in spite of the weak inhibitory stimulus which previously was able to produce distinct relaxation of the muscle. On restoring the full intensity of the inhibitory stimulus full relaxation returns once more. On withdrawing the inhibitory stimulus altogether a final rebound contraction occurs exhibiting still more marked post-inhibitory exaltation. Time in quarter seconds.

it did before [8]. In the decerebrate preparation the reflex inhibition of an extensor muscle is followed on removal of the inhibitory stimulus by a seemingly spontaneous rebound contraction of the muscle [9]. (Figs. 1 and 2.) This rebound is obtained even when all other nerves of the limb have been severed, except only that of the extensor muscle itself. It is, therefore, not necessarily dependent on the movement produced by the precurrent flexion-reflex, for, although the stimulus which inhibits the extensor muscle would produce the flexion-reflex were the limb musculature intact, the musculature having (except for the extensor muscle in question) been entirely paralysed by nerve-section, the flexion movement cannot take place. The rebound appears, therefore, of *central* origin. It is a sign of the exaltation of activity which commonly follows inhibition. But that that exaltation culminates in actual spontaneous discharge from the centre under rebound is doubtful. The post-inhibitory contraction of the extensor is probably a return in exaggerated measure of the tonic contraction of the extensors (antigravity muscles) usual in the decerebrate preparation. That tonic contraction is reflex, and due to a stimulus of proprio-ceptive kind. It is inhibited by the stimulus which causes the flexion phase of the step, and returns on withdrawal of that stimulus, and its exaggeration on return merely means that the proprio-ceptive stimulus which produces it finds the responsiveness of the extensor centres heightened after the temporary period of inhibition. The phenomenon is, therefore, simply another item of evidence that a *post-inhibitory exaltation* of spinal activity occurs in the nervous centres of the limb.

We may now attempt in the light of the above facts to trace the manner of production of the stepping reflex as excited by one or other of the various stimuli which evoke it from the skin of the decapitated preparation. These stimuli are remote, and they are of noxious character. In these respects they contrast with the intrinsic stimuli, *i.e*, the stimuli which excite the reflex when applied to this stepping limb itself. These latter are not cutaneous, and are innocuous and proprio-ceptive. Part of the problem pertaining to the reflex step lies in harmonizing the two sets of stimuli so widely different. We may take the case of a continued stimulus, *e.g.*, pressure or faradization applied to the skin of one hind-limb exciting reflex stepping in the other hind-limb. The stepping movement begins with active extension of the limb. It was shown that passive extension of the limb tends to excite an active reflex flexion of the limb, and does so by generating in the deep structures of the limb a stimulus which excites reflex flexion. In short, the primary remote stimulus, noxious and cutaneous, reflexly provokes an extension-movement of the limb, and this movement generates in the extending limb a secondary and proprio-ceptive intrinsic stimulus whose reflex effect on the limb is antagonistic to that of the primary stimulus. Thus arises a competition between two stimuli whose influences on the motor neurons of the limb are directly opposed one to the other. If the secondary stimulus prove strong enough there will ensue flexion of the limb in spite of the continued application of the primary stimulus. But with the occurrence of flexion the secondary stimulus will diminish and the primary stimulus will again assert itself, reinforced probably by a tertiary proprio-ceptive stimulus generated in the limb by the flexion of the limb and tending to produce extension. Extension therefore recurs and the process repeats itself as before. And in each of these changes from extension to flexion, and especially from flexion to extension, post-inhibitory rebound facilitates the change. Indeed, the burden of shunting from flexion to extension and *vice versa* is thrown greatly upon mechanisms wholly intrinsic to the cord. But the interference between the local proprio-ceptive stimulus and the remote continuous stimulus *regulates* the tempo at which the alternation, the shunting, proceeds.

A similar description applies conversely to the case where the remote stimulus, *e.g.*, faradization of the cross-section of the cord in the first cervical segment excites stepping of the ipsilateral hind-limb with flexion as the opening phase of the step. Here we may consider that we have a continuous stimulus to flexion broken in its operation recurrently and rhythmically by a local proprio-ceptive stimulus to extension, this latter secondary stimulus being engendered in the limb by the movement of flexion which the primary stimulus evokes. Here, again, the change from flexion to extension and conversely is facilitated by post-inhibitory rebound, of the inhibited extensor centres after flexion, of the inhibited flexor centres after extension.

And to this mechanism, and when the stepping is bipedal and involves *both* hind-limbs, must be added an adjuvant influence from the fellow hind-limb. The hind-limbs of the spinal dog show that when the initial posture of one hind-limb is flexion at hip and knee and of the other extension at those joints, on allowing the flexed limb to drop into extension the opposite limb at once flexes at hip and knee. And directly full extension is reached by the dropped limb active flexion occurs in it and is accompanied by active extension of the opposite hip and knee that have just previously flexed. This crossed reflex influence reinforces the mechanism producing the alternations of extension and flexion in the fellow-limb; it is so potent in some cases that arrest of the stepping in one limb soon causes cessation of the stepping in the other limb also. And this crossed influence is an important factor in keeping the phases of the stepping in walking and trotting correctly timed though converse in phase in the two limbs, right and left.

The experimental results in regard to reflex stepping point, therefore, to a mechanism comparable with that of the "Selbsteuerung" of the inspiratory movement discovered by Hering and Breuer[1] [4]. There it was shown that the contraction of the diaphragm in inspiration is in due course cut short by a reflex inhibition, traceable to a stimulus generated by the mechanical stretch which the inspiratory movement itself produces in the lungs, also by that of the diaphragm itself (Baglioni [1]). The inspiratory reaction is therefore arrested by a secondary reflex of its own making, a secondary reflex antagonistic to the primary reaction in regard to its influence on the respiratory muscles. Similarly in the case of the vasomotor centre and the heart, intense action of the general vaso-constrictor centre, by raising the aortic blood-pressure, stretches the aortic wall, and by so doing excites the afferent nerve of the aorta,[2] *n. depressor*, and through it reflexly depresses the action of the vaso-constrictor centre.

In these cases the primary reaction generates a secondary one antagonistic to the primary itself. Thus during reflex stepping a conflict recurs rhythmically between two stimuli of opposed influence on the limb musculature, or rather on the motor neurons of that musculature, one stimulus exciting the extensor motor neurons and inhibiting the flexor, the other inhibiting the extensor and exciting the flexor. The case of the concurrence of two stimuli having opposed influence on the motor neurons of one and the same field of musculature has been examined [10] for muscles which the reflex step actually engages—namely, those of the knee. The result of the competition between the opposed influences is found to fall into one or other of three types, according to the relative intensities of the opposed stimuli. (Figs. 3 and 4.) If A is a stimulus exciting motor neurons E and inhibiting motor neurons F, and if then a stimulus B arise whose influence is to inhibit motor neurons E and excite motor neurons F, the three types of result, as actually

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[1] Also Head [3], Gad [2], Lewandowsky [5].
[2] A. Tschermak and G. Koster [11].

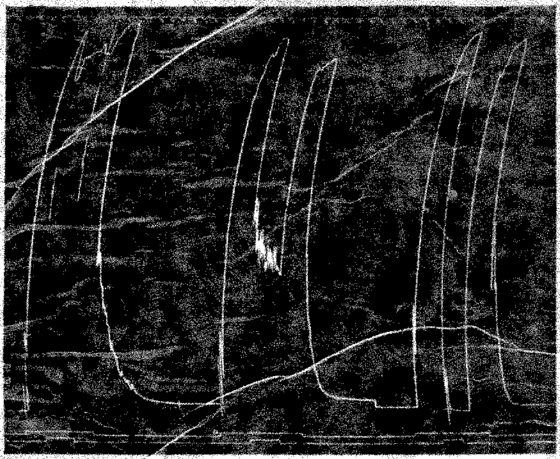

FIG. 3.

Reflex contraction of *vastocrureus* in spinal mammal (decapitated cat), excited by faradic stimulation of contralateral popliteal nerve (C). During this contraction the ipsilateral peroneal nerve was faradized for the time shown by the lower signal (I), and produced a lessening of the reflex contraction; this inhibitory effect is greater according as the intensity of the stimulation of the ipsilateral nerve is increased. In the second observation it reduces the reflex contraction to less than half; in the third observation it suppresses it altogether for so long as the inhibitory stimulus endures. In the third observation, with the strong inhibition, so abrupt and quick is the suppression of the contraction that the writing lever gives a vibratory shake at the end of its fall. The tremor seen to occur in the second observation during the period of concurrent excitation and inhibition is usual, and is more marked in the decapitated preparation than in the decerebrate. Time in seconds above.

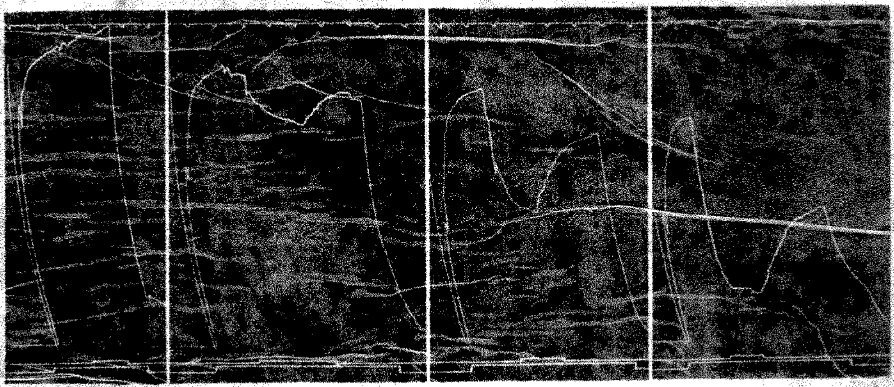

FIG. 4.

Reflex contractions of semitendinosus, a flexor of knee, evoked by stimulation of ipsilateral peroneal (I) nerve; the contraction is inhibited in each observation by an intercurrent stimulation of the contralateral popliteal nerve (C). The intensity of the ipsilateral stimulus—the excitatory—is progressively lessened from observation I to observation IV, while the intensity of the inhibitory stimulus (C) is kept the same for all the observations. Cat, decerebrate preparation. Time in seconds above.

observed, are as follows: If B is much weaker than A its inhibitory influence is unable to modify perceptibly A's excitatory influence, and A's inhibitory influence wholly prevents. B's excitatory effect from showing on the muscle. If B is much more intense than A, B's excitatory effect wholly overcomes A's inhibitory effect, to judge by the muscle, and B's inhibitory effect wholly suppresses A's excitatory effect. If A and B are of not very unequal intensity the excitatory effect which A is producing is partially suppressed by the inhibitory influence exerted by B, and the inhibitory effect which A is producing only partially suppresses the excitatory influence which B brings to bear. In other words, there results a contraction, both of the muscles E which A excites and of their antagonists, the muscles F, which B excites, but the contraction of E is less than it was when A was acting alone, and the contraction of F is less than it would be were B acting alone. In short, *double reciprocal innervation* is at work and the results of stimulus A and stimulus B sum algebraically in their effect, both on muscle E and on muscle F.

In the case of the reflex step, therefore, when the stimulus S, by its reflex effect on the limb-muscles, generates in the limb a local stimulus S′ antagonistic to S itself, the exact effect on the limb musculature depends on the relative intensities of S and S′. When the stimulus S is very intense as compared with S′, as is the case when a noxious stimulus is applied to the skin of the limb itself, S′ is unable to modify the effect of S, and the usual nociceptive unalternating reflex results, the protective reflex folding up the limb out of harm's way. When S is remote, and, therefore, as regards its efficacy on the distant limb, less intense, the intensity of S′ is sufficient to interfere with the effect of S, and the rhythmic alternating reflex, stepping, ensues. But it remains a question in any particular case whether the intensity of S′ is sufficient temporarily to suppress S's effect wholly or only in part. If the latter, and taking the case of S's effect being flexor, the flexor movement will change to extensor movement when S′s influence arises; the flexors will, under that influence be partially relaxed and the extensors will concurrently contract to some extent. My impression is that in many instances the reflex stepping of the decapitated preparation belongs to this form; *i.e.*, that the relaxation of the relaxing muscles is partial, and does not extend to complete suppression of all contraction, and similarly that the contraction of their opponents does not reach its maximum extent. This impression is strengthened by the analogous scratch-reflex, in which, in many instances, it can be seen that the rhythmic clonus is due to partial relaxations of a persistent contraction maintained throughout the reflex. Similarly, when the respiratory movements are quick and deep, the contraction of the diaphragm does not wholly cease during expiration; the diaphragm relaxes, but its relaxation is only partial. In the stepping of the decapitated preparation there is evidence that the effect of the remote nociceptive stimulus preponderates over that of the intrinsic proprio-ceptive stimulus. The former stimulus, when its locus of application lies in the median line of the perineum, causes a bipedal stepping which is remarkably similar in form in the two limbs right and left. But if the point of application of the stimulus be shifted somewhat to the right, the stepping of the right hind-limb, although its tempo is not altered, is characterized by greater flexion, especially at the hip, while that of the left limb, without alteration in tempo, becomes characterized by greater extension, especially at the hip. Now the stepping initiated from the base of the ipsilateral limb opens with flexion, while that initiated from the crossed limb opens with extension; in short, the remote stimulus is responsible in the ipsilateral limb for flexion, in the crossed limb for extension. It is clear, therefore, that in this case of reflex stepping the remote or initiatory stepping predominates over the intrinsic or secondary stimulus in each limb. And it is also clear, from this and other observations, that the exact form assumed by the reflex stepping of a limb is largely governed by the nature (locus, &c.) and intensity of the remote stimulus in relation to the secondary intrinsic one. By grading the rhythmic partial relaxations due to graded intensities of the two opponent stimuli S and S′, various forms can be given to the reflex step. Whether under the competition between the remote primary and the intrinsic secondary stimulus the third form of result ever ensues remains without direct answer from my observations. My impression is that, in the case of the more perfect reflex stepping of the spinal hind-limbs of the dog, after the period of shock has passed, it can be seen to occur. When that stepping is slow and ample, as it sometimes is, my impression is that flexors and extensors may fully relax alternately: just as in natural breathing the diaphragm may, for a short time, during the expiratory phase, show a complete absence of contraction.

As to the tempo of the stepping, a factor largely governing it is clearly the intensity of the remote initiatory stimulus. With increase of stimulus S the tempo of the step is quickened. This is well seen when the hind-limb stepping is excited by faradization of the cross-section of the bulb or cervical cord. Increase in the intensity of the stimulus does not prolong the excitatory effect; it gives an increased intensity of discharge followed at increased speed by a refractory period and alternation of phase, these latter also of shorter duration. Such a result harmonizes well with the view put forward by Verworn and Fröhlich as to the nature of refractory phase and inhibition.

It seems permissible to draw one conclusion from the experimental observations on reflex stepping at least in regard to stepping as naturally executed under the initiation of the higher centres, let us say although the expression has but vague connotation in physiology, under the mandate of the will. The inference from the experiments is, that in such a case the excitatory influence descending from the higher centres to the spinal centres of the limbs is not an intermittent periodic one whose periods determine the periods of the sequence of the steps, and still less does it consist of two alternating periodic influences—one determining the recurrence of one phase of the step, the other determining the recurrence of the other phase of the step. The excitatory influence descending to the limb centres is a continuous one, whose continuous operation is in a rhythmic manner completely or partially interrupted by an antagonistic reflex reaction secondarily generated in the limb. And when the continuously descending excitatory influence is intense, it provokes quicker steps than when it is less intense.

But the decapitated preparation, though it can perform stepping movements with its limbs, cannot effectively walk or run. The stepping of its fore-limbs is, in my experience, less easy to provoke and less perfect than in the hind-limbs. But there are other reasons also for its inefficiency as regards actual progression. One of these is its inability to support the erect posture. It cannot stand. The decerebrate preparation is less readily excited to step, but its stepping, when elicited, is much more effective and amounts in many instances to actual though imperfect progression (cat). Between reflex standing and reflex stepping the nexus is natural and close. The reflex stepping, when evoked in the limbs of the decerebrate preparation, clearly appears as a series of reflex flexions of each limb in turn breaking through the static postural reflex of standing and followed in each limb in turn by a return of the static reflex in exaggerated measure. The extensor phase of the step is much stronger in the decerebrate preparation than in the decapitated. An inference is that in the decerebrate preparation the same pre-spinal mechanism, in virtue of which the preparation can stand, contributes also to the extensor phase of the step. Probably it is shock consequent on loss of this pre-spinal mechanism which makes extensor-reflexes usually less easy to evoke than flexor in the decapitated preparation, and causes them to recover later in the spinal limbs after thoracic transection. It seems unnatural that experimental records in these "acute" preparations—the decerebrate and the decapitated—should find reflex stepping obtainable as a purely spinal reaction, while reflex standing is only obtainable where the hind-brain and part of the mid-brain remain in addition to the spinal cord. The answer seems to lie in the circumstance that the latter, the postural reflex, is an extensor reflex, whereas the former is only partly an extensor reflex and depends also on flexor mechanisms, and these mechanisms suffer less than extensor from removal of the pre-spinal centres so greatly adjuvant to the latter. In the frog, where the habitually resting posture on land is with hind-limbs flexed, the spinal preparation preserves well that reflex posture of the hind-limbs. The postural tonus of the hind-limbs of the frog is a flexor tonus, and the Brondgeest experiment shows the tonus there to be a static reflex dependent on the afferents of the limb; Bernard's observations showed, further, that the afferents involved are not those of the skin of the limb, but those of the deep structures. In short, like the standing posture of the hind-limb of cat and dog, it is a proprio-ceptive reflex from the limb itself.

The decerebrate preparation retains the reflex mechanisms for executing stepping movements, and also for supporting the erect posture; yet it is not very readily driven to exhibit reflex walking and running. To elicit locomotion in it the stimuli have to be intense, and such as are of a nature to evoke pain, did consciousness exist in the preparation. And with the locomotor movements thus initiated go pseudo-affective movements [12] of face and larynx suggestive of defence as well as flight. We may ask, what is the reason of this want of readiness of locomotor response in a preparation that still possesses so much of the neuro-muscular apparatus subserving such response? Is it because the intercollicular transection, by cutting off the great distance-receptors for olfactory, optic, and to a great extent acoustic stimuli, and all the superstructure concerned with sensuous elaboration of fillet impulses, has so reduced the creature's responsiveness that the mere static proprio-ceptive reflex of quiescent posture can engage it undisturbed? Has its world petrified to a motionless system, wholly static, an invariant monotone bereft of all symbolism of change? Has the mutilation involved removal of some nodal region habitually initiatory of progression? In absence of that focal region has it become difficult even for afferent channels still remaining to the creature to unify its reactions into so complex and wide a motor response as that involved in progression?

The observations of Goltz, and more recently of Rothmann, have shown that the dog, deprived almost wholly of both cerebral hemispheres, can stand and walk. Goltz's dog would, when feeding time approached, rear itself so as to rest its fore-paws on the gate of the kennel. In its roaming, it on one occasion wounded its hind-foot. It was then observed to walk on three feet, holding the injured foot off the ground. In even the decapitated preparation (cat) a somewhat similar reaction can be seen. If, as the preparation lies on its side, one hind-foot be forcibly pinched, this limb is flexed at the hip, knee, and ankle, and the other limbs at once begin rapid, co-ordinated stepping movements. The injured foot is held up out of harm's way, and the other legs run away.

Even in such a high animal type as the dog the whole complex act of reflex progression can therefore be performed not only without the collaboration of the cerebral cortex, but also in practical absence of the whole cerebral hemispheres themselves. That the posterior thalamic region is of importance in this connexion is indicated by the observations of several observers, and notably of Thiele. The red nucleus probably also contributes, as its recent analysis by v. Monakow indicates. The experiments of Horsley and of Thiele show that decerebrate rigidity is hardly seriously impaired by successive sections of the cerebellar region until the paracerebellar nuclei are invaded. In this problem of co-ordination, as in so many others, the justice and penetration of views long expressed by Hughlings Jackson meets us. More than thirty years ago Jackson wrote laying stress on the importance of the distinction between "continuous movements" and "changing movements." "In walking the cerebellum tends to stiffen all the muscles; the changing movements of walking are the result of "discharges overcoming in a particular and orderly way the otherwise continuous cerebellar influence." Under experimental procedure the two reflex elements, the static of erect posture and the kinetic furnishing rhythmic alternating movement of the stepping limbs, disengage themselves as separable components of the total reflex of progression. How exactly they are combined in such an act as walking remains for further elucidation, and we must, I think, for the present leave them with that question unanswered; the information before us seems still insufficient to solve the problem.

But we may glance back finally at the above component reflexes used in progression to look at certain principles of simpler co-ordination which they exhibit in their handling of the musculature of the limb. To take first the rhythmic diphasic motion of the limb which constitutes the step. It has already been mentioned that the muscles which are protagonists in the one phase are not so in the other; the protagonists of one phase are the antagonists of the other. And this is true equally for both phases. It is well seen when the musculature of the limb is analysed in regard to the part played by its several muscles individually in the respective phases of the step. In each phase certain muscles are found to be contracting and certain to be relaxing. In the flexion phase (fig. 5, A), the muscles which after appropriate isolation can be detected to be actually shortening by active contraction are *psoas*, *sartorius* (except perhaps lower part of lateral band), *rectus*, *gracilis*, *biceps femoris posterior*, *semitendinosus*, *tibialis anticus*, *extensor longus digitorum*, *peroneus longus*, *gluteus minimus*, and *tenuissimus*. On the other hand, certain muscles can similarly be detected actually to relax in this phase. These are: *semimembranosus*, *biceps femoris anterior*, *quadratus femoris*, *vastus lateralis*, *vastus medialis*, *crureus*, *adductor minor*, *gastrocnemius* and *soleus*. That these muscles relax during this phase of the step does not necessarily mean that they relax to such a degree that no contraction remains in them. It merely means that the grade of contraction which they exhibit at the outset of the phase lessens during the phase. The extent to which their pre-existing contraction relaxes is proportioned to the degree to which the contraction of the opposing muscles is augmented. And the relaxation is brought about by reflex inhibition of the centre innervating them, just as the augmentation of the contraction of the opponent muscles is due to reflex excitation of the centre innervating those muscles. MacDougall's drainage-theory very aptly expresses this result. Evidently the principle exhibited by the taxis of the reflex in handling these protagonists and antagonists is that of reciprocal innervation. It does not at all preclude the co-existence at one and the same time of a certain amount of active contraction in both protagonist and antagonist. What it does preclude, and what does not in fact appear ever to occur, is concurrent increase of contraction in both protagonist and antagonist, and concurrent decrease of contraction in both protagonist and antagonist. When excitation of the flexor motor neuron is being augmented by further excitation, that of the extensor motor neuron is by inhibition being correspondingly lessened; and conversely.

In the extension-phase of the step (Fig. 5, B) the following muscles

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are by analysis found to be contracting: *quadratus femoris, biceps femoris anterior, semimembranosus, vastus lateralis crureus, vastus medialis, adductor minor, gastrocnemius, soleus,* and *flexor longus digitorum.* The muscles observed to relax in this phase are: *psoas, sartorius, rectus femoris gracilis, semitendinosus, biceps femoris posterior, gluteus, minimus, tibialis anticus,* and *extensor longus digitorum.* In this phase, also, protagonists and antagonists are dealt with by reciprocal innervation.

Reference to the above lists, and to the accompanying diagram (fig. 5) illustrating them, shows, however, that in each phase of the step

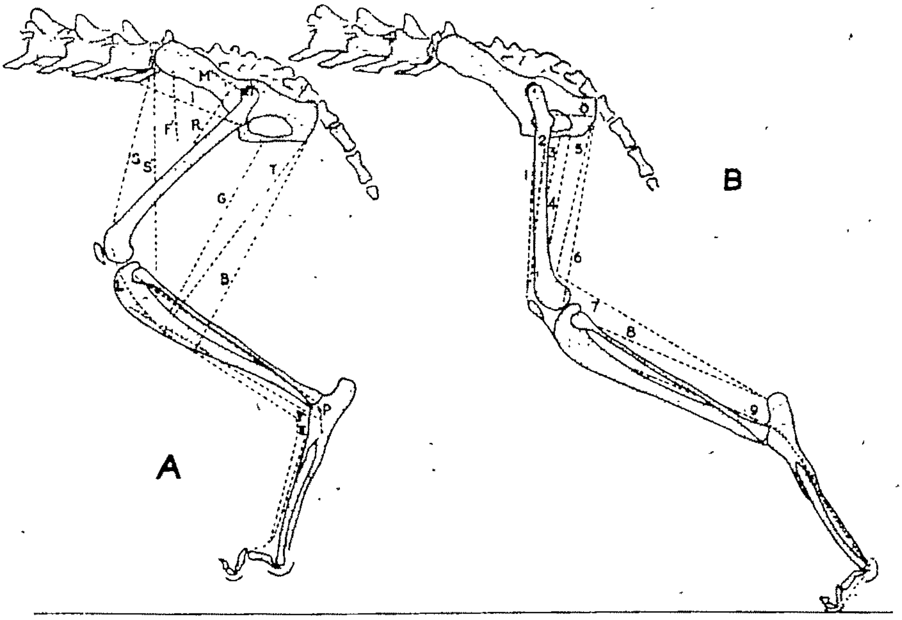

Fig. 5.

Figure illustrating the muscles actually observed by experimental analysis to be engaged in contracting in the flexion-phase A and in the extension phase B of the reflex step of the cat.

A.

A, tibialis anticus.
B, biceps femoris posterior.
E, extensor brevis digitorum.
F, tensor fasciæ femoris brevis.
G, gracilis.
I, psoas.
L, extensor longus digitorum.
M, gluteus minimus.
P, peroneus longus.
R, rectus femoris.
S, sartorius lateralis.
S', sartorius medialis.
T, semitendinosus.

B.

0, quadratus femoris.
1, crureus.
2, vasti.
3, adductor minor.
4, adductor major (a part).
5, semimembranosus.
6, biceps femoris posterior.
7, gastrocnemius.
8, soleus.
9, flexor longus digitorum.

certain muscles which, in a sense, are antagonistic to each other, are not dealt with by reciprocal innervation. That is, certain muscles which oppose each other's action are identically innervated, *i.e.*, are together excited to contraction, and are inhibited together and at the same time. A good example is that of the semitendinosus or biceps femoris posterior, along with the psoas or sartorius. The two former muscles are flexors of knee and also extensors of the hip; but though extensors of the hip they contract during the flexion-phase of the step when the hip is being flexed. The extension of the hip which they tend to produce is wholly prevented and overcome by the concurrent contraction of the psoas and sartorius (mesial band), which are in so far their antagonists. But this prevention of their mechanical effect at the hip enhances their flexor-effect at knee. Hence it is clear that the reflex taxis is such that the hip flexors, whilst protagonists of flexion at that joint, serve also as fixators for the protagonist flexors of the next joint, the knee. The reflex taxis employs the same muscles as protagonists at one joint, and as fixators for the protagonists of the next joint. This is a principle commonly to be observed in the reflex movements of the limbs in cat and dog. The reflex makes certain muscles, which in H. E. Hering's term are pseudo-antagonists, synergic with the protagonists for the sake of fixation of adjacent joints. These muscles, along with the protagonists it deals with by identical innervation, not by reciprocal innervation.

A similar case is that of gastrocnemius. In the extension phase of the reflex step this muscle contracts; it extends the ankle, and if acting by itself alone would flex the knee. But the reflex taxis is such that the muscle's flexor action at the knee is prevented. The knee extensor, vastocrureus, is thrown into contraction concurrently with the gastrocnemius. The vastocrureus, by preventing the gastrocnemius from flexing the knee, enhances the latter's action as an extensor of ankle. Again, when the ankle is flexed in the flexor-phase of the step, not only is the gastrocnemius the direct antagonist of the ankle-flexors relaxed by reciprocal inhibition, but so, likewise, is the vastocrureus. This last, on account of the origin of the gastrocnemius above knee-joint, is an indirect extensor of ankle. Vastocrureus and gastrocnemius, although partial or pseudo-antagonists, are by the reflex taxis made synergic and handled by identical innervation.

If we turn to the static reflex of standing, as exemplified by the purely reflex standing of the decerebrate preparation, we find in this postural reflex also the same principles observed as in the kinetic reflex of the step. Thus the protagonists which keep the knee extended are here, as in the extension phase of the step, the vasti and crureus. Main antagonists to these are semitendinosus, biceps femoris posterior, sartorius (medial band) and gracilis. In these antagonists, while their protagonists remain in steady tonic contraction, observation fails to show any contraction; on the contrary, it finds them under a slight degree of inhibitory restraint, the converse of the protagonist's degree of reflex excitation. Here, apparently, the static reflex, like the kinetic, deals with protagonist and antagonist by reciprocal innervation. The muscles which appropriate experimental analysis finds to be exhibiting tonic contraction in this postural reflex are the following: *quadratus femoris, semimembranosus, biceps femoris anterior, vastus lateralis, vastus medialis, crureus adductor minor, soleus* and *gastrocnemius;* probably also flexor longus digitorum, though in this last the tonic contraction is slight. And, here again, it is obvious that certain of the muscles exhibiting contraction simultaneously are nevertheless to some extent opponents of each other's action. Thus the gastrocnemius and vastocrureus are opponents in respect of their action at knee. Yet the reflex taxis makes them synergic muscles. And with the same result as in the kinetic reflex of the extension-phase of the step; the vastocrureus, by opposing the flexor action of the gastrocnemius at the knee, enhances the extensor action of that muscle at the ankle. These pseudo-antagonists are dealt with by identical innervation, not by reciprocal innervation, as are the true antagonists.

Finally, it may be remarked that the reflex taxis both of the step and of standing in many cases does not treat as functional units certain items of the musculature regarded as unit muscles by anatomical nomenclature. Thus it deals with the biceps femoris as a double muscle compounded of a pair of units, which have the mutual relation of protagonist and antagonist. The portion of the muscle which is inserted above the knee-joint it treats along with the extensors of the limb, that portion inserted below the knee-joint it associates with the flexors of the limb. Hence, in the account given above, a biceps femoris anterior has been distinguished from a biceps femoris posterior, because these are functionally dealt with by the reflex as two separate muscles. Similarly the reflex treats that part of quadriceps extensor which constitutes the rectus femoris as a flexor, while the rest of the quadriceps it relegates to the extensor mechanism of the limb. When the distribution of the knee-jerk in the muscular field of the limb is examined, one part of quadriceps is found to be unoccupied in the jerk-reaction—

that part is rectus femoris. This is undoubtedly connected with the circumstance that the reflex machinery of the limb treats the rectus as a flexor. It would seem that the jerk phenomena are all confined to those groups of muscles which were referred to as "anti-gravity" muscles, the muscles which by their contraction counteract gravity in the usual erect posture, the usustatus, of the animal.

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"A CONTRIBUTION TO THE LOCALIZATION OF CEREBRAL FUNCTION, BASED ON THE CLINICO-PATHOLOGICAL STUDY OF MENTAL DISEASE."[1]

BY JOSEPH SHAW BOLTON, M.D., F.R.C.P.

CHAPTER I.—General Remarks on Cortical Localization.
CHAPTER II.—Method of Investigation.
CHAPTER III.—The Lamination of the Normal Cortex and its Mode of Evolution.
CHAPTER IV.—The Lamination of the Visuo-sensory Area, the Visuo-psychic Zone, and the Prefrontal Region.
CHAPTER V.—Intracranial Abnormal and Morbid Appearances in Mental Disease. Generalization of Amentia and Dementia.
CHAPTER VI.—Micrometric Examination of the Cerebral Cortex in Mental Disease.
CHAPTER VII.—The Pre-Rolandic or Psychomotor Cortex.
CHAPTER VIII.—Provisional Scheme of the Localization of Cerebral Function.
CHAPTER IX.—The Nature of Language, and the Language Mechanism.
CHAPTER X.—Defective Control of Processes of Lower Association in Mental Disease.
CHAPTER XI.—Independent Activity of the Centres of Lower Association.—Illusion and Hallucination.
ADDENDUM.
APPENDIX A.
APPENDIX B.

MR. PRESIDENT AND GENTLEMEN, in thanking you for the honour you have done me by your invitation to deliver the Goulstonian Lectures for the present year, I wish at the same time to apologize for my presumption in choosing as my subject such a vexed and intricate question as the localization of cerebral function. I have but one excuse to offer—namely, that in my researches I have attacked this subject by a somewhat different method from any hitherto adopted, and have thereby obtained results which appear to me partly to confirm and partly to amplify the conclusions arrived at by certain other and more experienced workers. As my present investigations have already occupied a considerable period of time, it being now fourteen years since their commencement, and ten years since my first paper on cortical localization was published, I think I may fairly claim that the conclusions at which I have arrived are neither hasty nor ill-considered, and I therefore trust that you will regard these, and also the evidence which I am about to lay before you, as not entirely unworthy of your attention.

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[1] The Goulstonian Lectures delivered before the Royal College of Physicians of London on March 1, 3, and 8, 1910.

CHAPTER I.

General Remarks on Cortical Localization.

I do not propose to enter into a historical retrospect of the investigations of the past forty years, as for my purpose it is sufficient to refer briefly to those of the past decade. With regard to the earlier researches, I would remark that the experimental method of investigation which was introduced by Fritsch and Hitzig and by Ferrier, and continued by numerous workers, from whose names it would be invidious to make a selection, may be considered to have served its purpose with the publication of the researches of Sherrington and Grünbaum [19]. These, by linking together the conclusions arrived at by the experimental and the histological methods, resulted in the belated recognition of the neglected histological investigation of Bevan Lewis and Henry Clarke [16] on the cortical localization of the motor area, and gave an impetus to the latter method which has already been followed by a considerable amplification of our knowledge of the structure and functions of the cerebrum.

The last, but not the least important, of the researches to which I must refer before dealing with the published work of the past few years are those of Flechsig [11] on the development of the human brain by a study of the process of myelination. The division of the cortex cerebri, by this investigator, into the two great classes of "sensory centres" and "centres of association" raised a storm of discussion and dissent which is almost unprecedented in the history of research, and which, but for Flechsig, would have overtaken the workers of the past decade. Though many of the results obtained by Flechsig have failed to obtain credence, largely perhaps through the frequency with which he modified them in successive publications, his broad generalization has successfully withstood the fire of criticism, and forms the origin, if not entirely the basis, of our present knowledge of cortical localization by histological methods. In my personal opinion, which is based on my experience of the great differences which exist in the degree of development of fœtal and infantile brains of approximately the same age, Flechsig was injudicious in applying directly to the adult cerebrum the results he obtained from the investigation of such brains; but it is easy to be wise after the event, and it is probable that the researches of Flechsig would have attracted less attention had they excited less dissent.

During the past decade numerous publications have appeared on the subject of cortical localization by histological methods. In these several publications the whole cortex cerebri of man, and in many orders of mammals, has been mapped out into various histologically different regions; and in some instances proof of the functional significance of these has also been adduced. Further, the mode of evolution and functional significance of the different cell-laminæ of the cortex cerebri have been discussed from both the ontogenetic and the phylogenetic aspects.

As I purpose in these lectures to deal solely with the human cerebrum, it is unnecessary for me to refer, except as occasion serves, to such investigations as concern the cortex of the lower mammals. Amongst the publications which bear on cortical localization in man, those of two authors stand out prominently — namely, the "Histological Studies" of Campbell [10] and the series of monographs published since the year 1902 by Brodmann [8]. These authors have independently and elaborately mapped out into histologically different areas the whole human cortex cerebri as well as the cortex cerebri of certain orders of mammals.

The human maps of these authors, whilst differing considerably in detail, agree with one another much more than either of them resembles the maps of Flechsig. I have already indicated one reason why the map of Flechsig cannot be applied directly to the adult cerebrum. It will also be evident to you that, owing to the low development in the fœtus of the later evolved spheres of association, the projection areas must of necessity differ considerably in their relative size and distribution in the fœtus and the adult. Further, without going so far as Elliot Smith [20], who from the point of view of causation closely correlates fissuration and histological differentiation, although these differ very considerably in the adult cerebrum, I certainly regard histological differentiation as one of the causes of fissuration, others being arterial supply, and probably also certain mechanical conditions of growth. It is hence not surprising that the projection areas of Flechsig, taking for granted their correctness in the fœtus, do not bear the same relationship to the main cerebral fissures as do these areas in the adult cerebrum.

Compare the maps of Flechsig (figs. 1 and 2) with the maps of Campbell and of Brodmann. It will be noticed that the visuo-sensory area is much larger than in the adult, as is also the bodily sensibility projection centre, which, in the adult, lies entirely behind the fissure of Rolando. Flechsig, however, I may remark, expressly states that the majority of the projection fibres pass behind the central fissure. At the period when the experimentally-obtained Rolandic area was considered to be both pre- and post-Rolandic, and to be sensori-motor in function, its supposed distribution closely resembled the fœtal bodily sensibility area of Flechsig, and the two were regarded

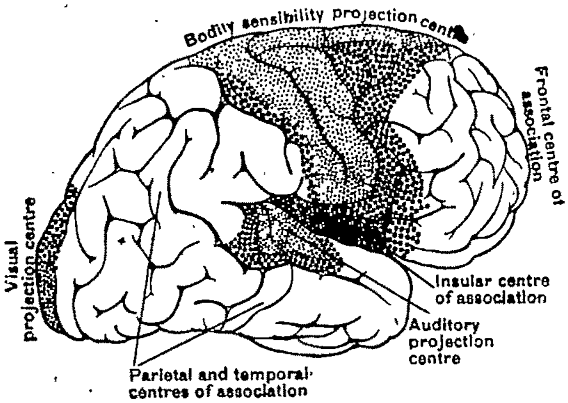

Bodily sensibility projection centre
Frontal centre of association
Visual projection centre
Insular centre of association
Auditory projection centre
Parietal and temporal centres of association

FIG. 1 (AFTER FLECHSIG).

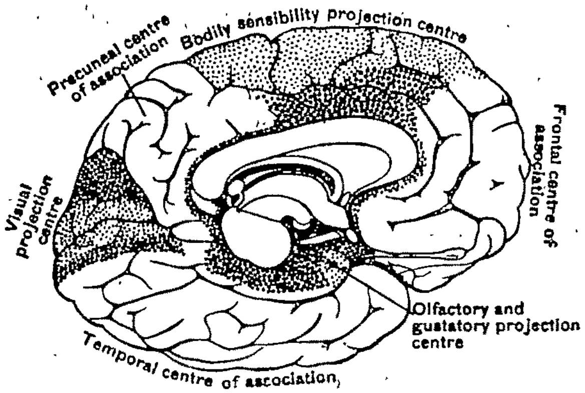

Precuneal centre of association
Bodily sensibility projection centre
Frontal centre of association
Visual projection centre
Olfactory and gustatory projection centre
Temporal centre of association

FIG. 2 (AFTER FLECHSIG).

In these diagrams the "centres of projection" and "centres of association" are mapped out according to Flechsig. The small dots are placed in the chief focus of each centre of projection. Around these chief foci are the regions to which a smaller number of fibres of projection pass; these are indicated by larger dots. These figures, which represent the different cortical spheres indicated by Flechsig as the result of his embryological studies, should be compared with figs. 3 to 6, and 7 and 8, which illustrate the various areas into which the adult cerebral cortex has been subdivided by Campbell and Brodmann respectively.

as identical. Now, however, the "motor" and "sensory" areas are regarded as separate and as lying on either side of the furrow of Rolando. It is, by the way, necessary to remark in this connexion, lest I should appear to disregard a recent article by Horsley [15], that I intend to refer to this when dealing later with the structure and functions of the psychomotor area.

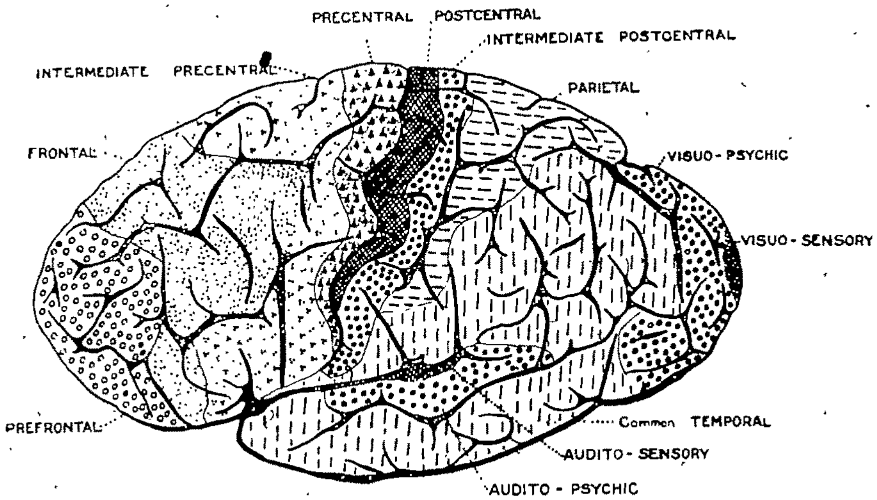


FIG. 3 (Campbell, 1904)

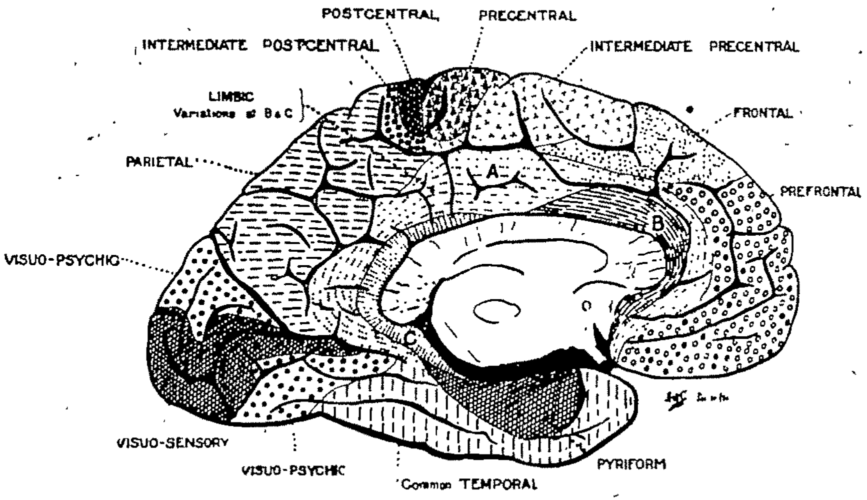


FIG. 4 (Campbell, 1904).

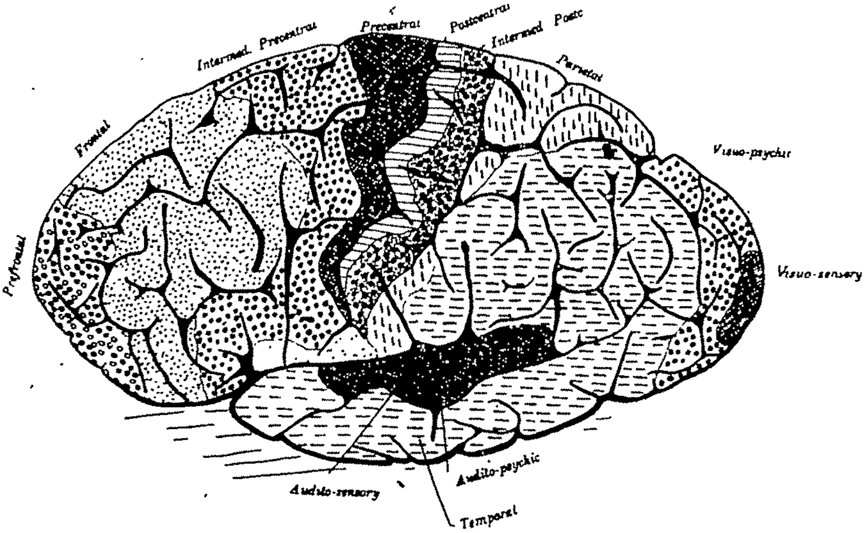


FIG. 5 (Campbell, 1905).

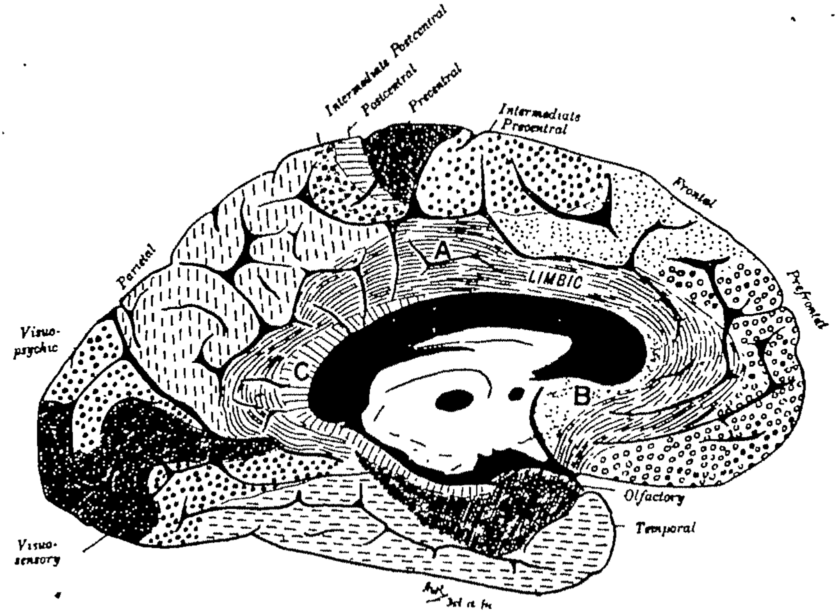


FIG. 6 (Campbell, 1905).

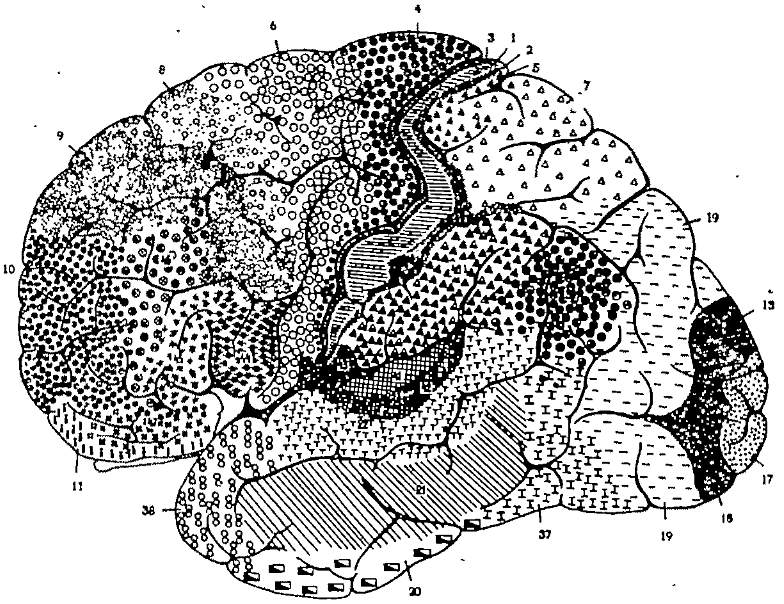


FIG. 7 (Brodmann, 1902-1907).

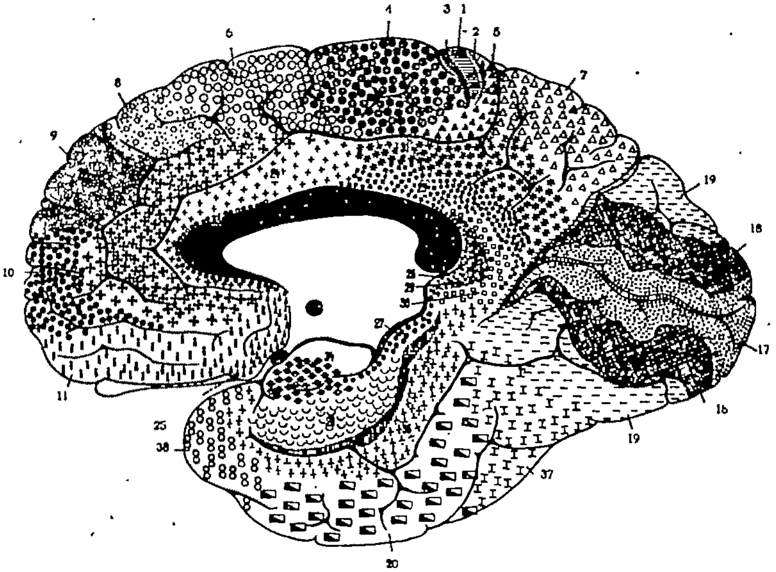


FIG. 8 (Brodmann, 1902-1907).

On figs. 3 to 8 I have arranged for comparison two sets of maps by Campbell, published in the years 1904 and 1905, and the maps of Brodmann.

In view of the great difficulties involved in cutting up, blocking, sectioning, orientating and reproducing in diagram form the cortex of entire human hemispheres, considerable differences might well be expected in maps prepared by two totally independent investigators. It is, however, difficult to understand the well-marked differences which exist in the case of the two pairs of diagrams of Campbell, one of which is contained in a preliminary communication, and the other, very shortly afterwards, in his monograph, since the fissuration of the two is identical. In the case of the prefrontal, the frontal, the parietal, and the visuo-psychic regions, the differences in distribution are very considerable, in view of the fact that, in the case of a particular brain, either the lines of demarcation should be very exact, say, within a millimetre in different copies of the same brain, or they should be left indefinite.

On the face of it, the maps of Campbell appear to be the more diagrammatic and the less accurate of the two sets; and this impression has been confirmed from my personal acquaintance with many regions of the cortex, particularly the frontal lobe and the visual areas. I would also refer to a recent paper by Gordon Holmes [13], on the histology of the post-central gyrus, in which the findings of Brodmann are confirmed.

I am, nevertheless, of the opinion, without disputing in any way the entire accuracy of these particular maps of Brodmann, that the exact differentiation of the greater portion of the grey mantle into such relatively precise areas as are the Betz-cell area and the visuo-sensory area will be attended with great difficulty owing to the probability that considerable differences exist in the case of different individuals, and especially so in the case of the poorly developed brains which are often met with in asylum practice. As an illustration of my meaning I have put together a diagram of six occipital regions [2] in which, many years ago, I precisely mapped out and obtained proof of the functional significance of the visuo-sensory area (fig. 9).

It will be noticed that both the shape and the apparent extent of this area differ considerably in the several cases, even when difference of age or the existence, in some, of long-standing blindness is allowed for.

Case 1 is a normal male aged 55 years.

Case 2, a female aged 17 years, is an example of chronic insanity with epilepsy.

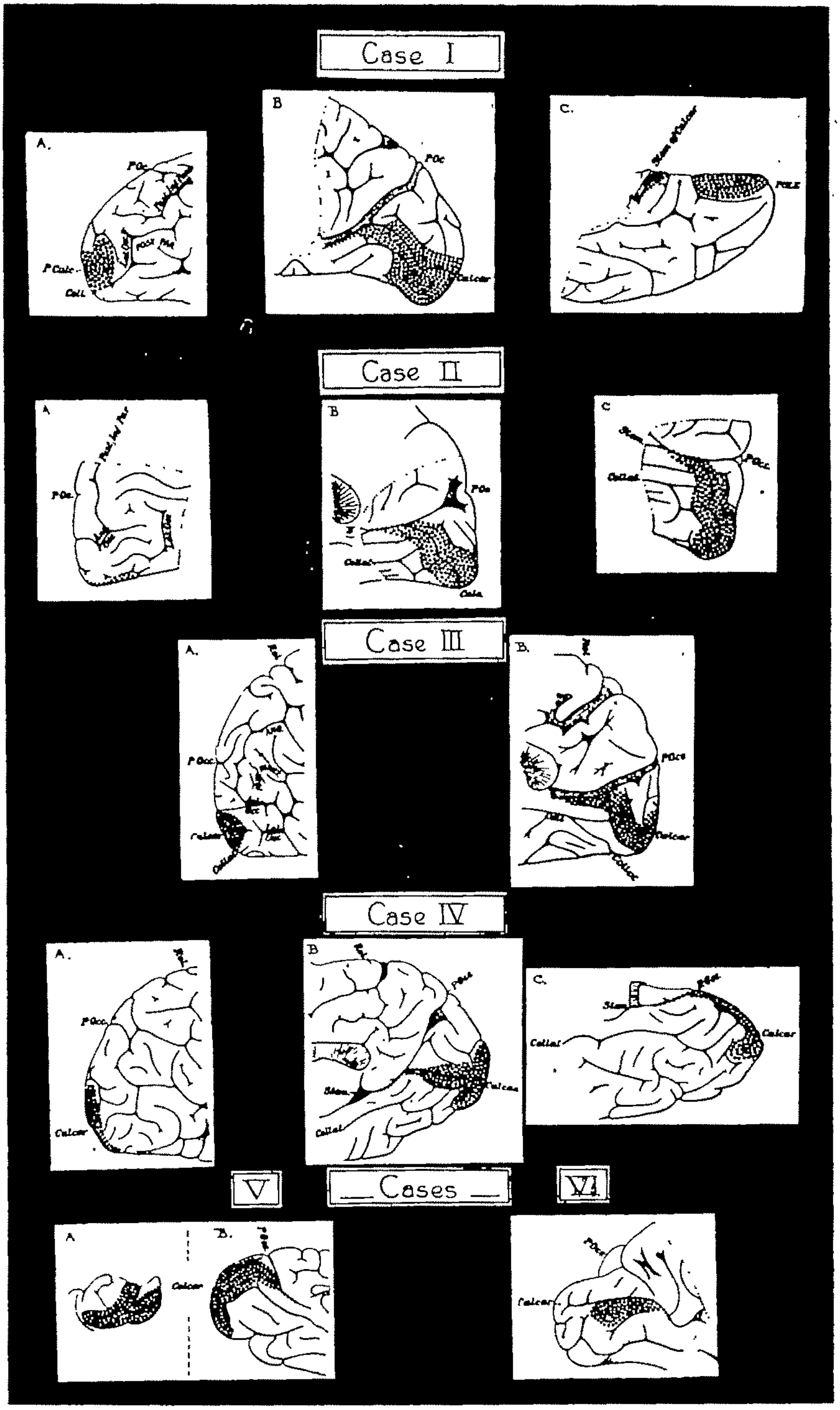


Fig. 9.

The figure illustrates variations in the distribution and the extent of the visuo-sensory area in different brains. Case 1.—Normal male, aged 55. Case 2.—Female, aged 17, chronic insanity with epilepsy. Case 3.—Female, aged 27, chronic insanity with blindness from infancy. Case 4.—Male, aged 30, chronic insanity with long-standing blindness. Case 5.—Normal infant, aged 3 months. Case 6.—Anophthalmos, aged 1 month. A = outer surface of hemisphere; B = inner surface; C = under surface.

Case 3, a female aged 27 years, is an example of chronic insanity with blindness from infancy.

Case 4, a male aged 30 years, is an example of chronic insanity with long-standing blindness.

Case 5 is a normal infant, male, aged 3 months, and

Case 6 is an example of anophthalmos, aged 1 month.

If such individual differences exist in a projection area of early evolution and stable organization, it is, to say the least, likely that still greater individual differences exist in the later evolved and later specialized regions of association.

As another illustration, this time of probable individual variation only, I will refer in a few words to the recent researches of Marie [18] concerning aphasia and the functions of the area of Broca. It may be accepted, as I have elsewhere [3] remarked, that the thesis of this author, with regard to the intellectual impairment exhibited by all aphasics, is true, at any rate if such cases be studied by methods familiar to the alienist. It is not, however, probable that motor aphasia is invariably the result of anarthria + sensory aphasia, although, on the other hand, it is doubtless true that anarthria + sensory aphasia necessarily give rise to the symptomatology of classical motor aphasia. It is certain that in the case of many persons Broca's speech centre is rightly disrated by Marie, whereas it is extremely probable that in others Broca's area is part of the educated psychomotor area, in which case its permanent loss would result in temporary "motor aphasia" with temporary interference with voluntary thought. Such variability with regard to the individual distribution of the special part of the psychomotor area which subserves the evolution of speech is, in my opinion, the only possible explanation of the widely divergent views which are held by equally competent observers.

Before concluding my reference to the histological differentiation of the cortex, I wish to mention quite briefly another question of importance. I have indicated the probability, if not certainty, that individual variations occur in the actual extent occupied by the several histologically differentiated areas which have been described. Whilst histological differentiation probably indicates the limits of possible educability, it does not, however, necessitate the existence of functional activity.

A very obvious illustration of this truth may be seen in the motor exhibitions evolved by the psychomotor area, which constitute the sole objective indications of cerebral activity. Whether we consider the infinite variety of skilled movements, the numerous highly complex written and spoken languages, or the wonderful gamut of expression and gesture of which the intelligent human subject is capable, we see in each case gross individual differences in educability. Histological differentiation probably supplies the key with regard to individual potentialities, but it is doubtful whether any single individual of the race has ever even approached the limits of his potential education.

I will trouble you with but one further illustration—namely, the remarkable manner in which such serious disabilities as congenital or early deprivation of the senses of hearing or sight may be compensated by education [14].

A person suffering from congenital or early loss of hearing is necessarily dumb; and, unless he live in association with other individuals suffering from the same disability, or be educated by special means, his mental functions differ little from those of the anthropoid apes. In such persons, under either of these conditions, the auditory disability is compensated for by shrewdness of vision, and the speech disability by the evolution of descriptive mimicry to a high standard. The deaf and dumb think by mimicry just as voluntary thought in normal persons occurs by the preliminary activity of the articulatory part of the psychomotor area, which is important evidence, if such be needed, in favour of the truth of the latter thesis. A normal individual may "think to himself" by means of invisible laryngeal and respiratory movements. A deaf-and-dumb person does not possess the same involuntary ability to hide the results of psychomotor activity during voluntary thought. Further, if such be taught lip-language, they readily learn to communicate with normal persons inexperienced in the special mimicry of the deaf and dumb.

On the other hand, the congenitally or early blind acquire language just as do ordinary non-reading and non-writing individuals, and, in the absence of special education, exhibit little or no defect of the mental functions. In such persons, however, loss of sight is usually compensated by marked hyperactivity of the sense of touch; and by means of special type the blind are able to acquire education which is often little, if at all, inferior to that of many normal individuals.

After these general remarks, I pass to the subject I purpose laying before you—namely, the evidence which I have obtained from the clinicopathological study of mental disease, with regard to the functional significance of certain special cortical areas.

I have hitherto confined my attention to four of the numerous regions into which the cerebral cortex is divisible—the visuo-sensory area, which is the best example of the sensory projection spheres; the visuo-psychic zone, which is one of the regions of special cerebral association; and the prefrontal (higher psychic) and precentral (psychomotor) regions.

As necessary preliminaries, I shall now describe in detail the method which I have employed, and also the manner in which the cortex cerebri undergoes evolution during fœtal life and infancy.

CHAPTER II.

Method of Investigation.

The method which I am about to describe, and which I have employed for many years, is that of micrometric measurement of the primary cell- and fibre-laminæ of the cortex. Neither in detail nor in results is it in any way comparable with the macro- and micrometric mensuration of grey matter which has been performed by several workers for many years, and it is therefore not necessary for me to refer further to this.

For reasons which I shall indicate later, I am accustomed to subdivide the cortex, for the purposes of measurement, into the five primary laminæ from which it has been evolved—namely, (1) the *outer fibre-lamina* or superficial layer; (2) the *outer cell-lamina* or pyramidal layer; (3) the *middle cell-lamina* or granule-layer; (4) the *inner fibre-lamina* or inner line of Baillarger, which in certain regions contains such bodies as the Betz cells and the solitary cells of Meynert; and (5) the *inner cell-lamina* or polymorphic layer. These five laminæ may more or less readily be identified in all parts of the neopallium, though they differ in their degree of development in different cortical areas. For example, in the psychomotor area, the third lamina is of minimal depth and can only be detected by careful examination. On the other hand, in the visuo-sensory area, the third lamina is of great depth, the granule-layer being duplicated by the interposition in its midst of the fibre-layer of Gennari, in which terminate the fibres of the optic radiations.

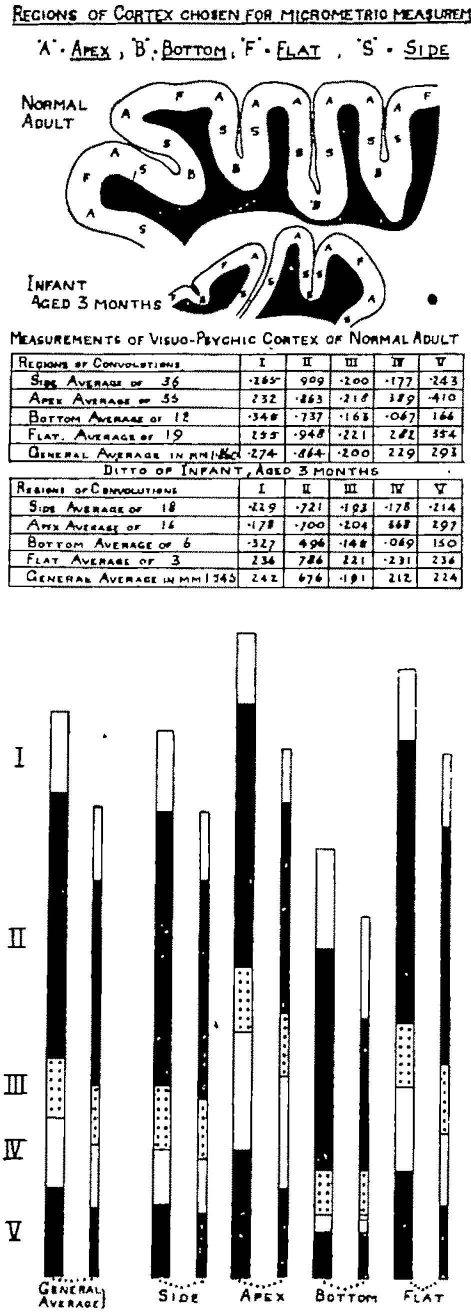
For the micrometric examination of the cortex it is, however, not sufficient merely to determine the laminæ which it is proposed to measure. Granted that accurately vertical sections are obtained, it is further necessary to define the exact regions of the convolutions which are capable of measurement. In theory the flat external surface of the convolutions is the ideal region, and in certain fœtal brains it is the only one which is available. In practice, however, its sole employment is impossible, if only for the sufficient reasons that a trustworthy number of situations is rarely available, and that its degree of development varies greatly, being very different over broad and narrow convolutions. I consequently employ four regions of the convolutions, and from these prepare a general average measurement. These regions are the *flat surfaces* or external parts between fissure lips, the *apices* or fissure lips, the *bottoms* of fissures, and the *sides* of fissures at some point between the apices or fissure lips and the bottoms of the fissures.

These regions are shown in the diagram (fig. 10).

It is perhaps hardly necessary to remark that in any given section, though it be cut ever so truly, many obliquities exist, and only a certain number of regions can be selected. In fact, it is by no means easy to obtain the necessary number of regions for measurement, and it sometimes happens that cases of promise have to be rejected, even after all the sections have been cut and stained.

The four well-defined regions to which I have referred are alone capable of accurate micrometric measurement, and for reasons which I shall now give, it is possible, after a sufficient number of measurements from these have been averaged, to obtain a trustworthy general average measurement from the four, which can be employed for the comparison of case with case.

Taking the four regions in turn, in the case of the *flat surface*, the fourth and fifth laminæ, and usually the third, are above the general average measurements, in some broad flat surfaces slightly, and in some narrow ones markedly. In the case of the *sides* of fissures, laminæ four and five are, as a rule, below the general average measurements, and considerable variation as regards total depth occurs in this region. As, however, many side measurements are, as a rule, available, it is relatively easy to obtain a trustworthy average. Flat surfaces and sides thus, in a measure, when taken together neutralize the defects inherent to each. In the case of the *apices*, the first two laminæ are, as a rule, slightly below the general average measurements, whereas lamina three is usually slightly above, lamina four is markedly above, and lamina five is considerably above the general average measurements. Lastly, in the case of the *bottoms* of fissures, lamina one is considerably above the general average measurement, and lamina two is slightly below, lamina three is moderately below, lamina four is very



REGIONS OF CORTEX CHOSEN FOR MICROMETRIC MEASUREMENT
"A" · APEX, "B" · BOTTOM, "F" · FLAT, "S" · SIDE
NORMAL ADULT
INFANT AGED 3 MONTHS
A
B
F
S
I
II
III
IV
V
GENERAL AVERAGE
SIDE
APEX
BOTTOM
FLAT

MEASUREMENTS OF VISUO-PSYCHIC CORTEX OF NORMAL ADULT

REGIONS OF CONVOLUTIONS	I	II	III	IV	V
SIDE AVERAGE OF 36	·265	909	·200	·177	·243
APEX AVERAGE OF 55	232	·863	·218	389	·410
BOTTOM AVERAGE OF 12	·346	·737	·163	·067	166
FLAT. AVERAGE OF 19	255	·948	·221	282	354
GENERAL AVERAGE IN MM 1·860	·274	·864	·200	229	293

DITTO OF INFANT, AGED 3 MONTHS

REGIONS OF CONVOLUTIONS	I	II	III	IV	V
SIDE AVERAGE OF 18	·229	·721	·193	·178	·214
APEX AVERAGE OF 16	·178	·700	·204	368	297
BOTTOM AVERAGE OF 6	·327	496	·148	·069	150
FLAT AVERAGE OF 3	236	786	221	·231	236
GENERAL AVERAGE IN MM 1·545	242	676	·191	212	224

FIG. 10.

The figure illustrates the method of micrometric measurement. In the upper portion of the figure are shown the four regions of the convolutions, which alone are capable of satisfactory measurement. In the middle part the results of the micrometric measurement of the visuo-psychic cortex of a normal adult and of an infant aged 3 months are given. In the lower portion the different cortical laminæ are shown graphically. These from above downwards are (I) the outer fibre- or superficial lamina; (II) the outer cell- or pyramidal lamina; (III) the middle cell- or granule-lamina; (IV) the inner fibre-lamina or inner line of Baillarger; and (V) the inner cell- or polymorphic lamina. On the left-hand side are shown the general average measurements obtained from a normal adult and an infant aged three months respectively; and on the right-hand side the average "side," "apex," "bottom," and "flat" measurements from which these general average measurements are produced.

much below, and lamina five is greatly below the general average measurements. Apices and bottoms, when taken together, thus to a great extent neutralize the defects inherent to each, and it is probable that, when a general average measurement is made from all four regions, a result is obtained which differs little from the measurements that would be obtained were the whole cortex a smooth, flat surface without fissures. Such a general average measurement as I have described, I believe to be entirely satisfactory for the comparison of different cases with one another.

In the diagram are illustrated the general average measurements of a normal case, and of an infant aged three months, and also the average measurements of the sides, apices, bottoms, and flat surfaces of each of these cases.

I would remark here that these differences in the depths of the several laminæ in the four regions are susceptible of a mechanical or structural explanation, which serves as a further justification for the employment of the four for the production of a general average measurement, since different cases, and also different cortical areas, vary in the degree to which such variations occur.

As has been remarked, at the apices the outer two laminæ are decreased, the third is slightly increased, the fourth is more than doubled, and the fifth is much increased. In the case of the flat surfaces a similar increase occurs in the lower three laminæ. At the bottom of the fissures, on the other hand, whilst the first lamina is increased, all the others, especially the fourth, are decreased; and in the case of the sides the fourth and fifth laminæ are somewhat decreased.

It is probable that these variations are due to the folding of the grey matter, for at the apices the convex outer surface would from this cause be relatively more extended and the laminæ consequently be thinned, whilst, on the contrary, the inner layers would be much crowded and increased in depth, this condition being intensified by the radiating manner in which the cortico-petal and the cortico-fugal fibres would necessarily have to pass in order to reach the convex surface. Owing to this radiation of fibres, some slight thickening should also occur in the third lamina. On the other hand, at the bottom of the fissure the first lamina would necessarily be thickened, owing to the large mass of fibres it would have to contain in spite of the relatively abrupt bend; and for the same reason the deeper layers would be thinned, partly because they occupy a relatively large convex area compared with the abrupt bend of the outer laminæ, and partly because of the relatively smaller number of cortico-petal and cortico-fugal fibres which would require to pass through their convex extension of surface. If to this be added that the surface convexity is necessarily larger in extent than the sharp bend at the bottom of the sulci, owing to the fact that fibres have to pass to and from all the surface parts of the cortex along the centre of the gyrus, and that the larger the external portion becomes the more acute is the bend at the bottom of the fissure, the mechanical or structural explanation of local variations in depth appears to be an entirely satisfactory one.

In individual cases gyri vary greatly in size, and the bends at the bottoms of fissures vary greatly in acuteness. Hence, regional variations differ in degree according to the particular case.

Lastly, from the aspect of different cortical areas, in the case, for example, of the visuo-sensory area many more fibres pass to the cortex than in the case of the visuo-psychic region, and in conformity with this fact the thinning of the layers at the bottoms of the fissures of the former (though actually less in degree) is relatively much more definite than is the alteration in depth of the various laminæ of the apices and flat surfaces; in other words, the gyri are more rounded, the layers are less moulded by position, and at the same time the bends at the bottoms of the fissures are relatively more abrupt.

For these various reasons I think it must be ceded that a general average measurement obtained from average measurements of the four regions I have defined is entirely trustworthy for the comparison of cases with another.

In the case of this and the following lecture, the measurements which I purpose to present in diagrammatic form have all been prepared in this manner. As the conclusions which I draw from them depend entirely on the accuracy of the method which I have adopted, I have thought it necessary to deal with this method in considerable detail.

A word is here necessary with regard to the method of preparation of the tissue employed. All the hemispheres have been hardened in 5-per-cent. commercial formalin; and the sections, though prepared and stained by different methods, have all been mounted in canada balsam. I was at one time of the opinion that different methods of sectioning and different methods of staining might result in quite different micrometric results; and my various series of cases were kept distinct from one another—e.g., cases cut by freezing or in paraffin, or stained by modified Nissl or ammonia-iron-alum-hæmatoxylin, &c. Comparison of the various micrometric results obtained from the same or different cases, cut and stained by the same or different methods, has, however, satisfied me that the question of method is of no importance, granted that the tissues are hardened and mounted in the same manner. The original hardening reagent appears to determine once for all the bulk of the hardened tissue, and any modifications which occur later, in consequence of the reasonable employment of reagents of different specific gravities, become readjusted when the tissue has been finally mounted in canada balsam.

The micrometric measurements are made by means of a Zeiss A objective and a No. 2 eyepiece with a tube of 160 mm. They are then reduced to micro-millimetres by the constant (14·73) of this particular combination.. As the constant varies somewhat in the case of different lenses of the same manufacture, I have throughout my work rendered the results strictly comparative by the employment of a microscope and lenses for the special purpose of micrometric measurement.

The special regions of the human cortex cerebri which I have hitherto dealt with by this method are the visuo-sensory, the visuo-psychic, and the prefrontal, as the most satisfactory examples available of projection, hall-marked or special associational, and higher associational cortex. The reasons for this selection will appear later.

I have, in all, measured fifty-four regions in thirty-eight hemispheres, which were obtained from thirty-seven cases of various types, including three fœtuses, two stillborns, three infants, four normal cases, and twenty-five examples of various types of mental disease, grading from the idiot with very deficient cerebral evolution, through imbeciles, recent, chronic and recurrent non-demented lunatics, and partially demented lunatics, to the gross dement with great cerebral dissolution.

Of the fifty-four regions measured, fifteen are visuo-sensory, fifteen are visuo-psychic, and twenty-four are prefrontal.

The visuo-sensory and visuo-psychic results are from the same cases, and in theory it would appear desirable that all the regions should have been examined in every case. In practice, however, this has been impossible, owing to the laborious nature of the work and the length of time it has been in progress. It has also been found to be unnecessary, on the one hand because the differences in measurement are well marked and definite, and on the other because the results of prefrontal measurement are of a different type from those obtained from the visuo-sensory and visuo-psychic regions. I may add that it has, in consequence, been possible up to the present to measure a much larger series of cases than would otherwise have been available. I have, however, specially selected a suitable, well-marked case, and measured all the three regions, in order to obviate such a possible criticism, and to prove the points to which I have just referred.

CHAPTER III.

The Lamination of the Normal Cortex and its Mode of Evolution.

I purpose demonstrating in the second lecture that the essential physical basis of mental disease consists, on the one hand in an imperfect development of the cell-laminæ of the cortex which is of the nature of a true sub-evolution, and on the other in degrees of decrease of the cell-laminæ which are of the nature of a true involution or dissolution, since such decrease in depth takes place in the converse order to that in which the cell-laminæ are developed during the process of normal growth.

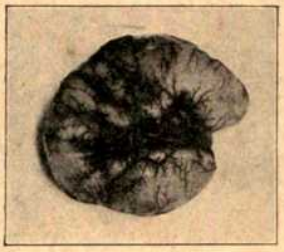


FIG. 11.

Outer surface of the right hemisphere of a male fœtus, aged a little over four months. Weight, after hardening in formalin, 32 grm. The fissure of Sylvius and a depression which occupies the site of the future fissure of Rolando are present, as also are numerous vascular grooves. Figs. 11, 13, 15, and 17 are of the same relative size.

As one of the necessary preliminaries to this demonstration, it is therefore desirable to describe in some detail the normal mode of evolution of the lamination of the cortex. For this purpose I shall employ the prefrontal region, since this is the portion of the cerebrum which is the last to be normally evolved, and also the area in which are present in maximum intensity those indications of sub-evolution and involution which occur in cases of mental disease.

The plates which I shall now describe are intended to show from the general point of view the manner in which the lamination of the cortex becomes evolved. All the microphotographs of this series are of exactly the same magnification.

The first photograph represents the right hemisphere of a human fœtus of about four months (fig. 11). The fissure of Sylvius and a depression which occupies the site of the future fissure of Rolando are present, as also are numerous vascular grooves.

In the following microphotograph (fig. 12) is shown a section of the prefrontal cortex. This will be seen to consist of a layer of

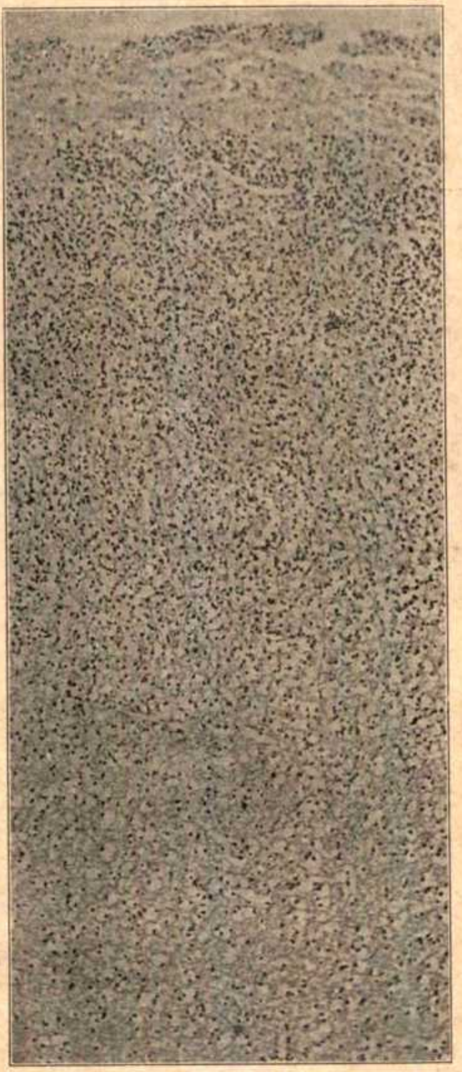


FIG. 12.

One hundred and nine diameters. The prefrontal cortex of the hemisphere shown in fig. 11. It consists of a layer of undifferentiated neuroblasts covered by a superficial layer of neuroglia into which irregular masses of neuroblasts project.

undifferentiated neuroblasts covered by a superficial layer of neuroglia, into which irregular masses of neuroblasts project. The neuroblasts are most closely packed towards the surface, and, at about the level of the lower trisection, indications exist of commencing differentiation of the nerve cells. The cortex has not begun to laminate, and its total depth is less than one-half of that of the normal adult.

In the next photograph (fig. 13) is shown the left hemisphere of a fœtus of about six months. The brain is somewhat larger and firmer, and the main fissures are defined or appearing. The numerous vascular groves seen in the previous hemisphere have largely or entirely disappeared, and the prefrontal region of the cortex consists simply of a flat external surface.

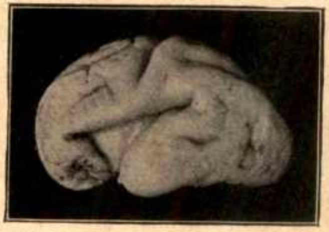


FIG. 13.

Outer surface of the left hemisphere of a fœtus, aged a little over six months. Weight, after hardening in formalin, 55 grm. The main fissures are defined or appearing, and the brain is larger and firmer than that shown in fig. 11.

The prefrontal cortex, as is seen in the microphotograph (fig. 14), shows little increase in depth, but definite signs of the commencement of the process of lamination. The inner cell-lamina or polymorphic layer is being separated from the rest by the development of the inner fibre-lamina or inner line of Baillarger. The middle cell-lamina or granule-layer is visible, owing to the shape and mode of aggregation of its constituent cells, and the outer cell-lamina or pyramidal layer can also be made out, and exhibits a partially columnar arrangement of its constituent cells in its lower two-thirds, and a massing together of the cells in its upper third. It will be at once evident to anyone familiar with the appearance of the adult cortex that development is taking place from within outwards, and that the superficial laminæ, especially the outer cell or pyramidal, are as yet of very deficient depth, the last being only about one-fourth of the adult normal.

It will be noted, on comparing the fourth and sixth months' fœtuses, that the development of lamination is coincident with greater firmness of the brain and disappearance of the numerous vascular grooves, rather than with any notable increase in the complexity or size of the hemispheres. Microscopically, however, an important advance has occurred—namely, the commencement of the process of lamination and a cleavage of the neuroblasts into an upper and a lower portion. In view

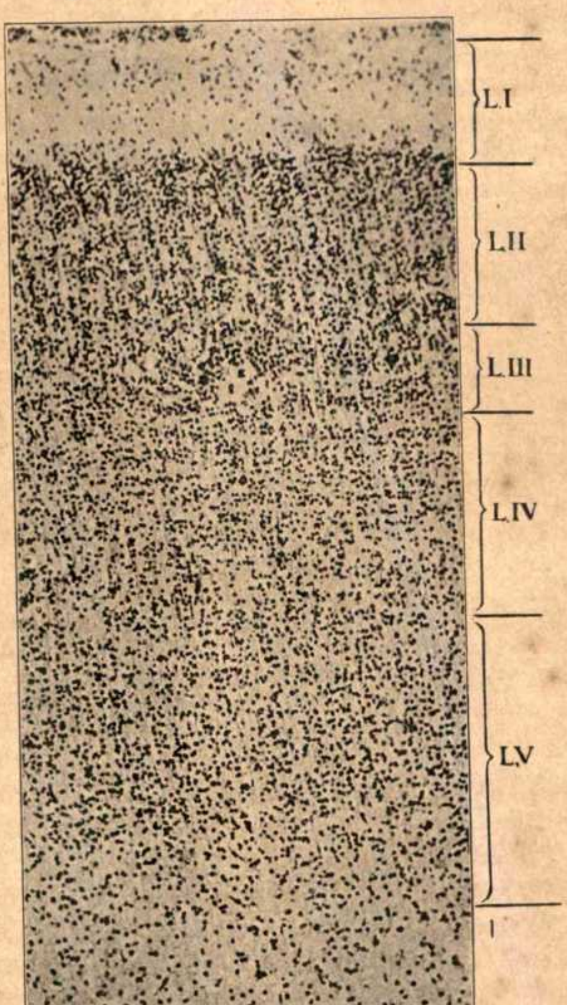


Fig. 14.

One hundred and nine diameters. The prefrontal cortex of the hemisphere shown in fig. 13. The process of lamination has commenced. L.I, the outer fibre-lamina. L.II, the outer cell- or pyramidal lamina. L.III, the middle cell- or granule-lamina. L.IV, the inner fibre-lamina. L.V, the inner cell- or polymorphic lamina.

of the evidence I shall produce with regard to the functions of the inner cell-lamina, I would remark that this early cleavage of the partially differentiated neuroblasts of the cortex into an upper and a lower portion is an occurrence of the greatest significance.

The next photograph (fig. 15) is of the right hemisphere of a fœtus of seven to eight months. The fissuration is completed, with the exception of the less important sub-sulci, and the brain has a general resemblance to that of the adult.

As is shown in the accompanying microphotograph (fig. 16), marked progress has taken place with regard to the development of the cortex and the differentiation of the nerve cells. The inner cell-lamina is clearly marked off by the inner fibre-lamina from the middle cell-lamina, and the outer cell-lamina or pyramidal layer shows a notable increase both in the depth of its lower part and in the degree of differentiation of the constituent cells of this. The upper portion of this lamina is still in a poorly differentiated condition, and the aggregation of its embryonic constituent cells is by contrast more visible than is the case in the fœtus of six months.

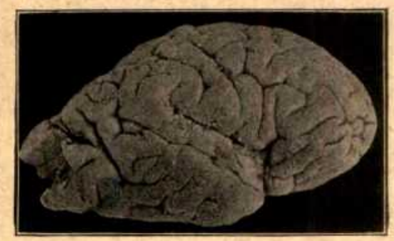


FIG. 15.

Outer surface of the right hemisphere of a fœtus, aged 7 to 8 months. Weight, after hardening in sublimate and formalin, 56 grm. The fissuration is completed, with the exception of the less important sub-sulci.

In the next photograph (fig. 17) is shown the unstripped right hemisphere of a stillborn male infant. The resemblance to the adult appearance of the brain is now well marked.

In the microphotograph (fig. 18) it will be seen that the cortex now exhibits a general resemblance to that of the adult. The nerve cells have largely taken their permanent form, and, being less embryonic and smaller, appear less crowded. A further important factor in causing less aggregation of cells is the increased superficial area of cortex, and the consequent smaller number of cells in a section of the same thickness. The outer cell-lamina or pyramidal layer is, however, still little more than one-half of the adult normal depth,

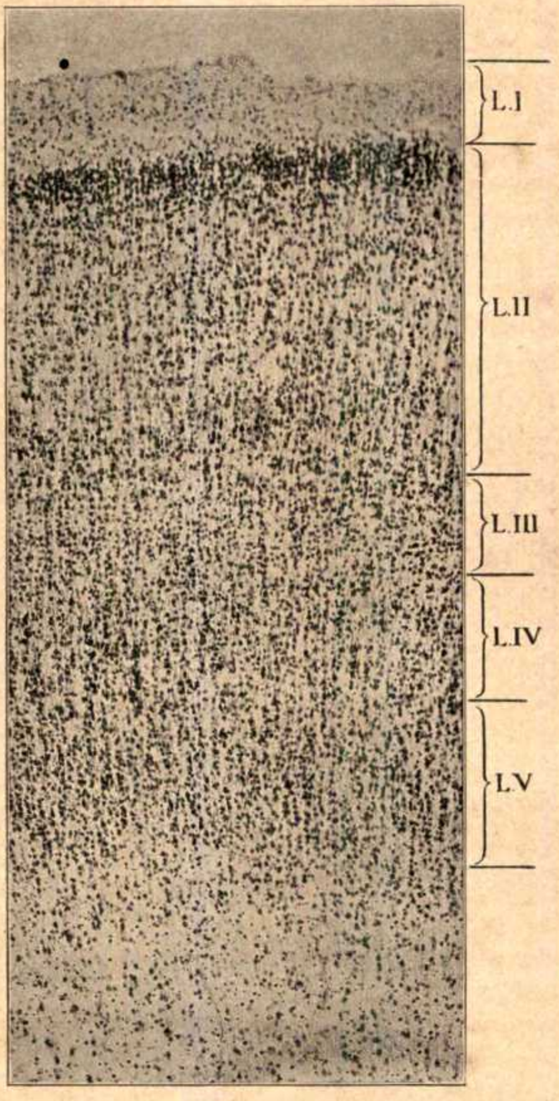


FIG. 16.

One hundred and nine diameters. The prefrontal cortex of the hemisphere shown in fig. 15. L.I to L.V as in fig. 14, L.II, the outer cell- or pyramidal lamina, though the latest to develop, has already become the deepest layer of the cortex. In the upper portion of this lamina the aggregation of its embryonic constituent cells is by contrast more visible than is the case in the fœtus of six months.

and exhibits a very obvious aggregation of embryonic cells in its upper part.

In contrast to the preceding microphotographs, the plate on p. 51 (fig. 19) illustrates the depth and general appearance of the adult normal cortex. The magnification is five-sevenths of that of the preceding microphotographs.

It was originally my intention to follow the further development of the cortex in children of different ages, but I found that such notable individual differences in the degree of the development of the cortex occurred as precluded the possibility of obtaining definite results. This truth is the anatomical counterpart of the known great individual differences in degree of mental development which exist in infants and young children.

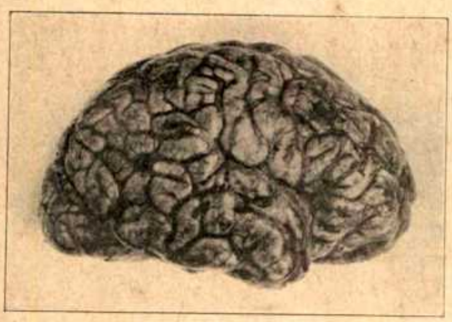


FIG. 17.

Outer surface of the unstripped right hemisphere of a male full-term stillborn child. Weight, after hardening in formalin, 194 grm. The fissure of Sylvius remains somewhat open, and its posterior limb is very oblique. The prefrontal region is small.

In the diagram on p. 52 (fig. 20) are shown, in percentages of the normal, the general average measurements which I have obtained from the prefrontal cortex of a number of cases. They clearly indicate the point to which I have just referred. The second case, though it falls well into series with the remainder, exhibits certain differences in the depth of the fourth and fifth laminæ which are due probably to the fact that all the measurements are from the flat external surface, owing to the absence of fissures. The fourth and fifth cases exhibit the individual differences in degree of development which I found to occur in two stillborn infants; and the case in the sixth column, that of a marasmatic infant of retarded general development, is also interesting in that the outer cell-lamina is of less depth than that of the second stillborn, whilst all the other laminæ are of almost

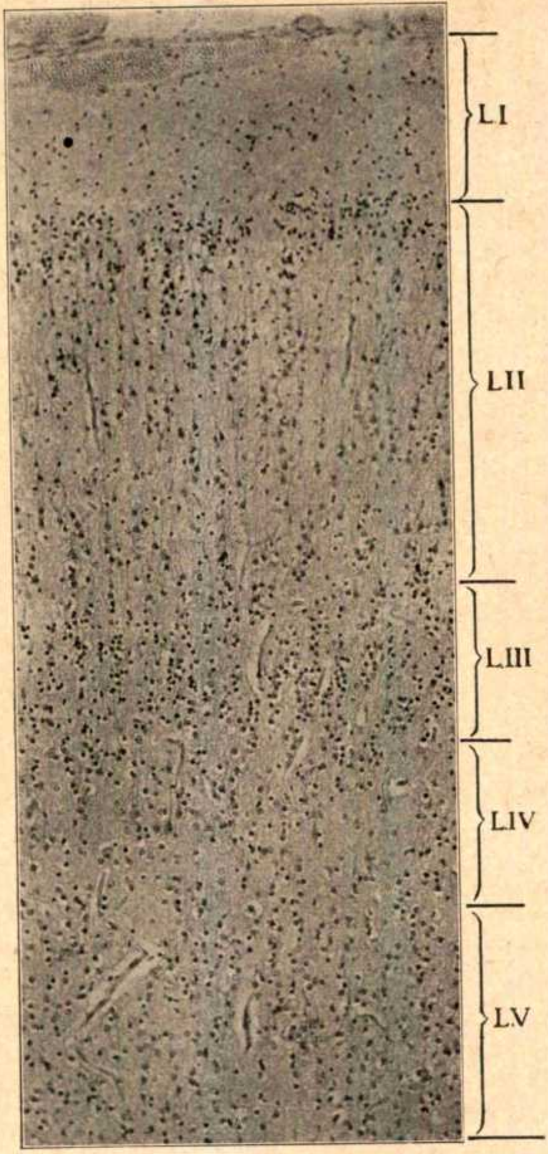


FIG. 18.

One hundred and nine diameters. The prefrontal cortex of the hemisphere shown in fig. 17. L.I to L.V as in preceding microphotographs. The cortex much more resembles that of the adult. L.II, the outer cell- or pyramidal lamina is, however, still little more than one-half of the adult normal depth, and exhibits a very obvious aggregation of embryonic cells in its upper part.

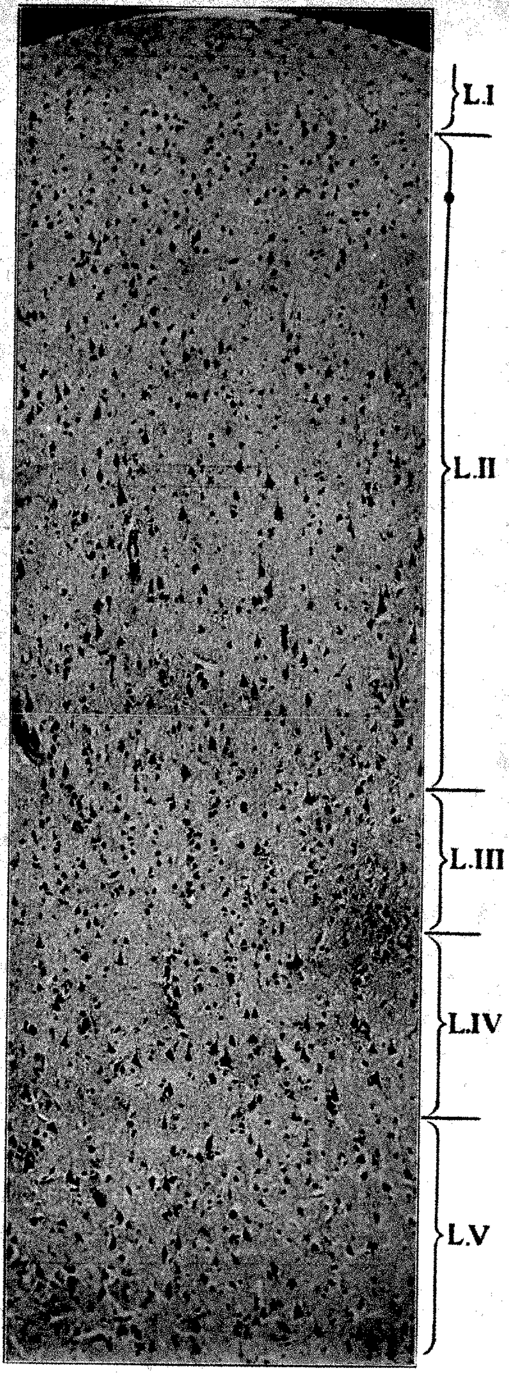


FIG. 19.

Seventy-six diameters. The prefrontal cortex of the normal adult. The magnification is five-sevenths of that of the preceding microphotographs. L.I to L.V as in previous figures. It should be noted that the depth of L.II is greater than the conjoined depths of L.III to L.V.

exactly the same depth as are those in the latter. Further, the diagram shows quite definitely that the laminæ are evolved from within outwards, and that the inner cell-lamina approaches the adult

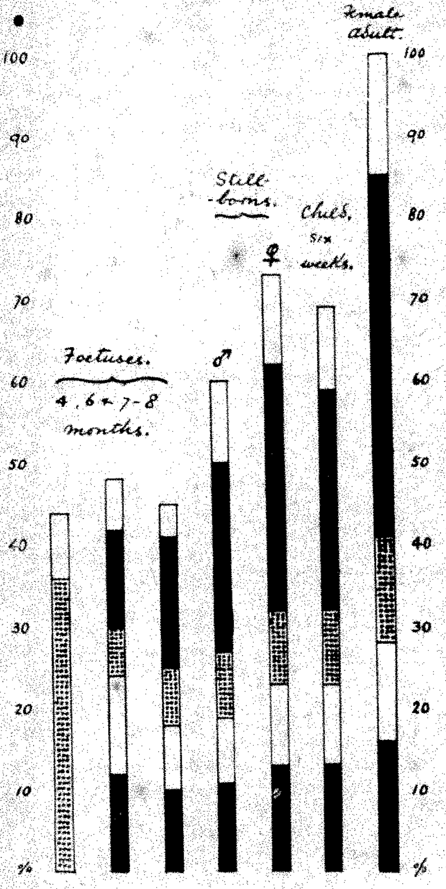


Fig. 20.

The figure shows, in percentages of the normal, the general average measurements of the prefrontal cortex of a series of fœtuses and infants. The actual measurements of these cases, together with other details concerning them, are summarized in Appendix A. The laminæ from above down are as in preceding figures. The illustration indicates that the cortex evolves from within outwards, the inner cell-lamina being the first to appear and rapidly attaining almost to the adult depth, and the outer cell-lamina the last, this lamina at birth being still only about one-half of the adult normal depth.

normal depth at birth, at which date the middle cell-lamina is about three-fourths, and the outer cell-lamina still little more than one half of the adult normal depth.

The same order of evolution of cortical lamination applies, judging from sample observations I have made, to the whole neopallium, though differences exist, both with regard to the degree of development of the different laminæ and to the date at which it occurs.

The outer cell-lamina or pyramidal layer, for example, in the visuo-sensory area attains in the adult to but five-ninths of the adult normal average depth, and elsewhere, as far as my observations extend, is of more constant depth, with measurable individual variations. The middle cell-lamina or granule-layer, in the visuo-sensory area, is hypertrophied and duplicated by the interposition of the fibre-layer of Gennari; its total depth, including this, being about three-and-a-half times its depth generally. On the other hand, in the psychomotor area, the granule-layer reaches a minimum depth, and is with difficulty discernible. The inner cell-lamina is of very constant depth. It is somewhat shallow in the visuo-sensory area, though proportionately less shallow than is the outer cell-lamina in this region.

With regard to the date at which evolution of the cortical laminæ occurs, I have at present merely sufficient evidence to show that it takes place earlier in the visuo-sensory area (projection sphere) than in the visuo-psychic (zone of special association), and earlier in the latter than in the prefrontal region (zone of higher association).

This evidence is shown in the following diagram (fig. 21), in which are collected a series of observations on the cortex of certain fœtuses, infants, and adults. The following are the chief points illustrated in the figure. In the visuo-sensory area of the infants of one and three months, the whole of the cell-laminæ have attained to almost the normal adult depth, and the outer cell-lamina is rather better evolved in the former than in the latter, in spite of the existence of congenital blindness in that case. On the other hand, in the visuo-psychic zone none of the laminæ are so far evolved, and the outer cell-lamina of the infant of one month is much shallower than that of the infant of three months. The visuo-sensory cortex is thus obviously evolved earlier than is the visuo-psychic. A further interesting point shown in the diagram is the low evolution of the middle cell-lamina, or receptive layer, of the cortex of the congenitally blind infant of one month, and the almost adult development of this in the infant of three months. The same detail is visible in the case of the visuo-psychic region, and this alone is sufficient to hallmark the visuo-psychic region as a zone of special visual association, especially when it is noted that this lamina is in the infant of three months of practically the adult depth, whereas

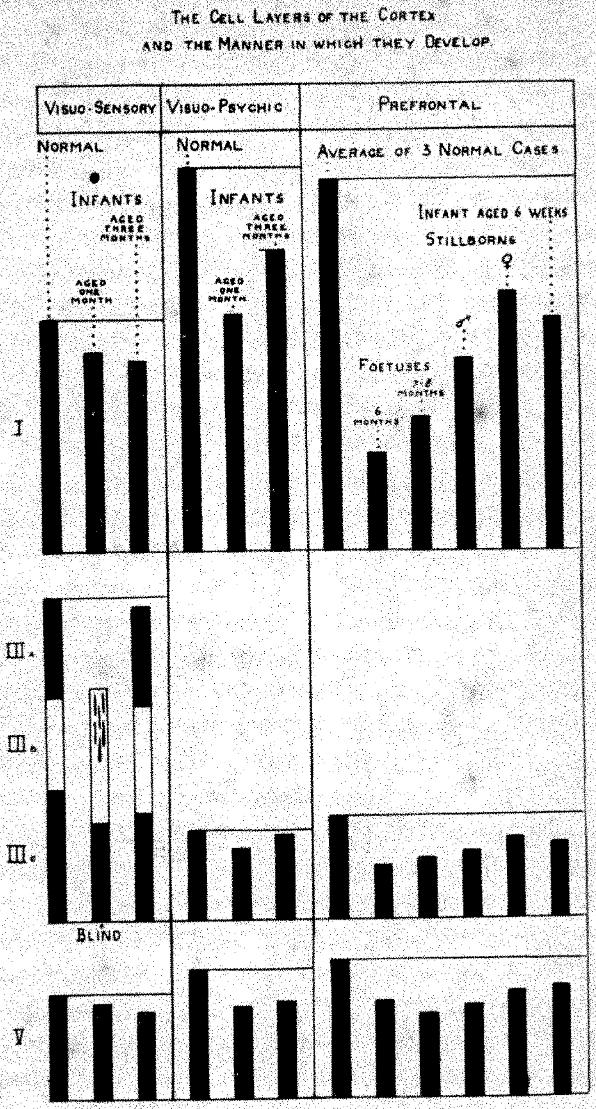


FIG. 21.

The figure shows the mode of evolution of the cell-laminæ of the cortex of the visuo-sensory, visuo-psychic, and prefrontal regions. The bottom series represents the inner cell- or polymorphic lamina, the middle series the middle cell- or granule-lamina, and the upper series the outer cell- or pyramidal lamina. A description is given in the text, but in general the figure suggests that the visuo-sensory cortex develops before the visuo-psychic, and this before the prefrontal; that the inner cell-lamina develops before the middle, and the middle before the outer; and, finally, that in the visuo-sensory and visuo-psychic regions the middle cell- or granule-lamina is the receptive lamina of the cortex and develops more rapidly than does the inner cell-lamina of these regions. The measurements from which this table is compiled, together with other details concerning the cases contained in it, are summarized in Appendix A.

the inner cell-lamina of this case is by no means so well developed. In other words, the granule- or receptive-lamina of the visuo-psychic zone follows the order of its evolution in the visuo-sensory area in being ahead of the inner cell-lamina in its degree of development.

In the case of the prefrontal region, though the results are not comparative, they are sufficient (especially when combined with other data to which I shall refer later) to indicate that evolution is individually variable, and occurs at a later date than is the case in either of the other two regions.

CHAPTER IV.

The Lamination of the Visuo-sensory Area, the Visuo-psychic Zone, and the Prefrontal Region.

I now propose to illustrate the lamination of the regions of the cortex which are under consideration, and in the case of the prefrontal area it is my intention, for reasons which I shall presently detail, to describe at some length its general structure. I would add that the microphotographs I am about to exhibit are of different magnifications, as it is necessary that the whole depth of the cortex should be present.

As the lamination of the visuo-sensory area is somewhat difficult to analyse without special experience, the first microphotograph (fig. 22) I shall exhibit is prepared from this area in the rhesus, in which the various laminæ are exceptionally well defined.

The layers shown in this specimen from above downwards are the outer fibre-lamina, or superficial layer; the outer cell-lamina, or pyramidal layer; the middle cell-lamina, which consists here of two granule-layers separated by the fibre-layer of Gennari, to which pass the terminal fibres of the optic radiations; the inner fibre-lamina, or inner line of Baillarger; and the inner cell-lamina, or layer of polymorphic cells.

In the next plate (fig. 23) is shown an average section of the same area in the normal adult. The same lamination is present, but it is more difficult to identify, and naturally still more difficult to measure.

[A photograph was shown illustrating the lamination of the visuo-psychic zone of the normal adult.] The five laminæ of which it is composed can readily be discerned. These are from above downwards the outer fibre-lamina, or superficial layer; the outer cell-lamina, or pyramidal layer; the middle cell-lamina, or granule-layer; the inner fibre-lamina, or inner line of Baillarger; and the inner cell-lamina, or layer of polymorphic cells.

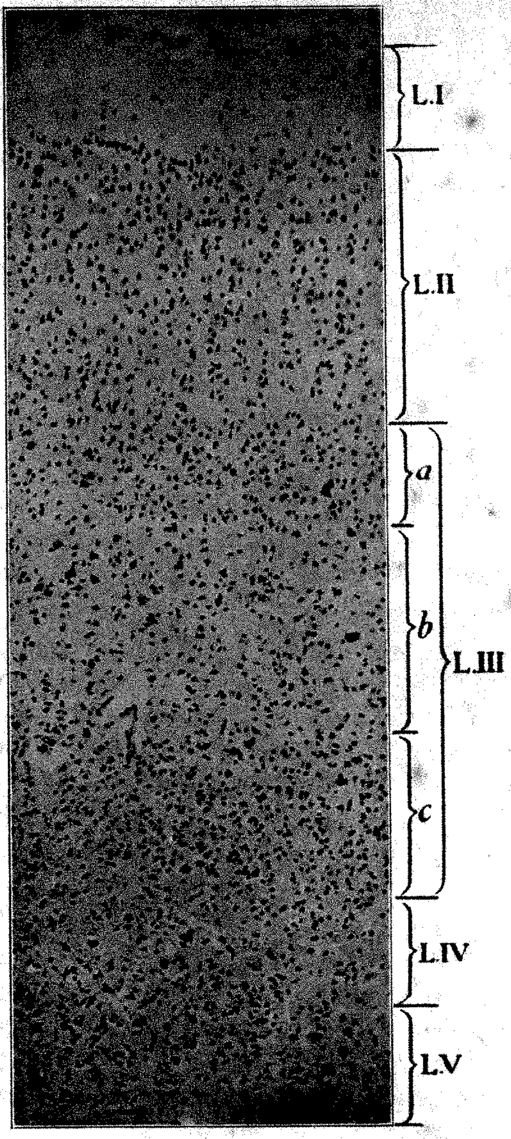


FIG. 22.

One hundred and nine diameters. The visuo-sensory cortex of the rhesus. L.I, the outer fibre- or superficial lamina. L.II, the outer cell- or pyramidal lamina. L.III, the middle cell- or granule-lamina, which is composed of two layers of granules, (*a*) and (*c*), separated by the horizontal fibre band of Gennari (*b*), in which terminate the fibres of the optic radiations. L.IV, the inner fibre-lamina or inner line of Baillarger. L.V, the inner cell- or polymorphic lamina.

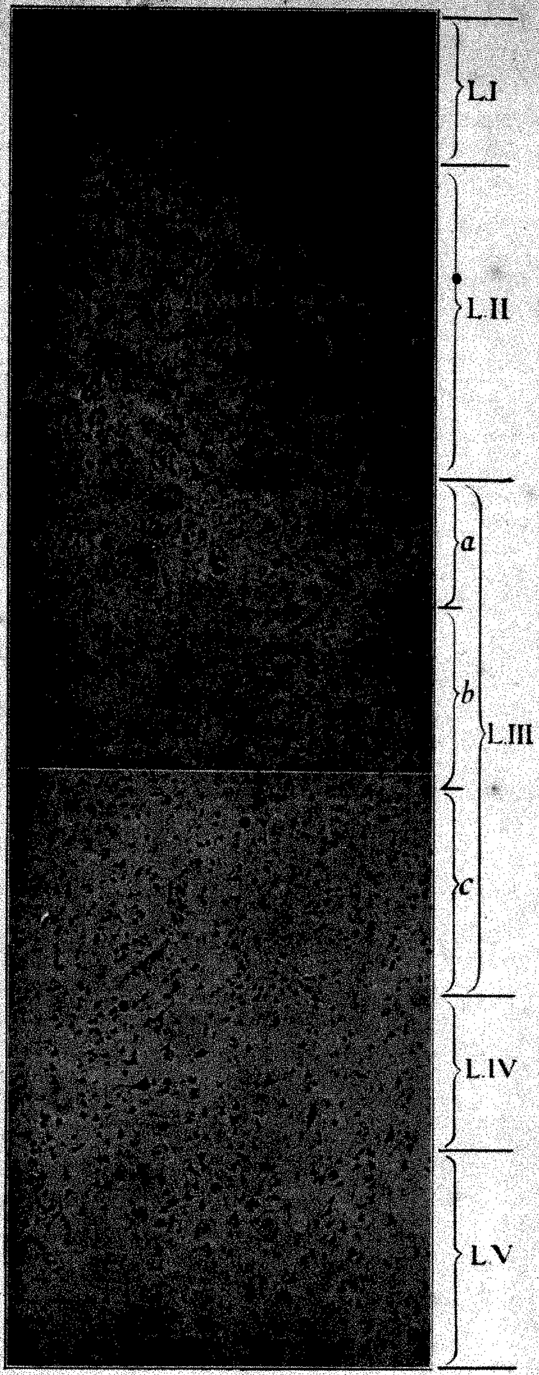


FIG. 23.

Ninety diameters. The visuo-sensory cortex of man. L.I to L.V, as in fig. 22. The lamination of the human visuo-sensory cortex is not easily recognized without special experience, but the different laminæ can be identified without difficulty if the figure be compared with the microphotograph of the visuo-sensory cortex of the rhesus, in which the various laminæ are very clearly defined.

[A photograph was also shown of a section through the periphery of the visuo-sensory area to display the manner in which the visuo-sensory cortex passes abruptly into the cortex of the visuo-psychic zone.] It will be seen that the line of Gennari suddenly ceases and the two layers of granules run into one, which occupies the site of the inner of these,

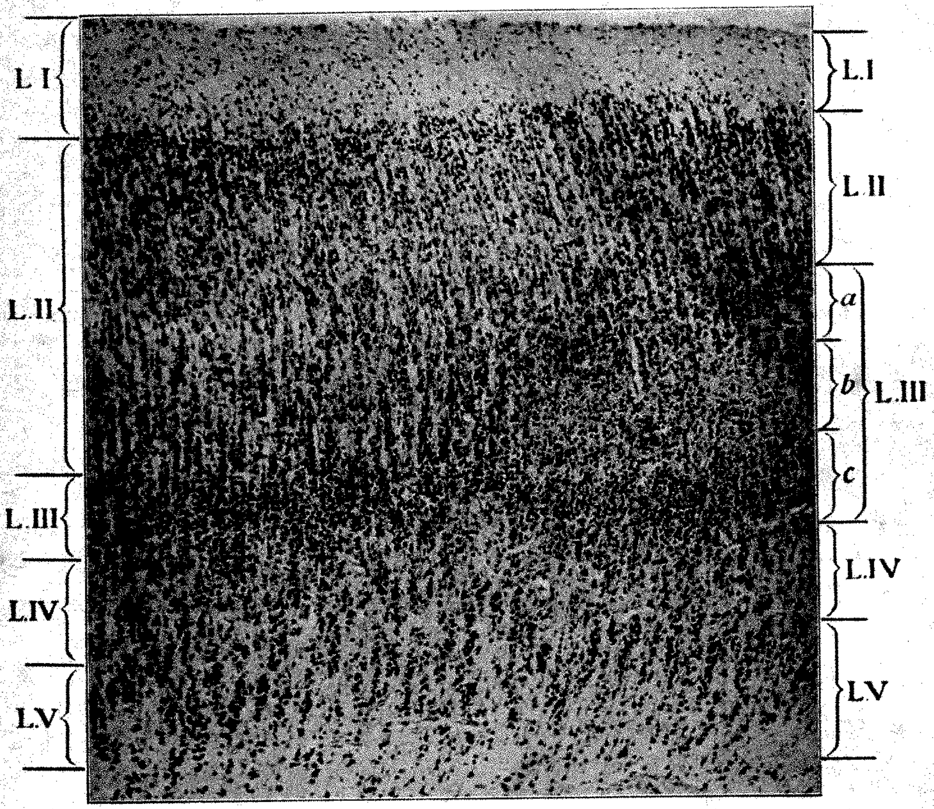


Fig. 24.

One hundred and nine diameters. The cortex of a seven to eight months' fœtus. The microphotograph is prepared at the periphery of the visuo-sensory area, and shows the passage of the visuo-sensory cortex into the visuo-psychic. L.I to L.V are as in the preceding illustrations; L.III*a* and L.III*c* are the two layers of granules, and L.III*b* is the intermediate fibre-layer or line of Gennari, of which three layers the middle cell-lamina consists in the visuo-sensory area. In the centre of the illustration it will be noted that the line of Gennari, L.III*b*, ceases, and that the layers of granules, L.III*a* and L.III*c*, run into one to form the granule-lamina, L.III, of the visuo-psychic cortex. A comparison of this figure with fig. 16, which illustrates the prefrontal cortex of the same case, very clearly demonstrates that the visual cortex of this case is much more advanced than that of the prefrontal region in its degree of development. These figures thus afford a partial graphic illustration of the truth that the visuo-sensory cortex develops before the visuo-psychic and the latter before the prefrontal.

the outer cell- or pyramidal lamina at the same time increasing to almost double the depth.

The same points are seen with perhaps greater clearness in the section (fig. 24) from a human fœtus of 7 to 8 months. A comparison of this illustration with an earlier one (fig. 16), which shows the prefrontal region of the same case, indicates that this last is in degree of development far behind the cortex of the visuo-sensory and visuo-psychic regions, which, particularly the former, much more closely resemble the adult type.

I think it quite certain that the outer layer of granules is the additional feature in the visuo-sensory area for three reasons: (1) The cortex normally evolves from within outwards. (2) The deeper layer of granules is of remarkably constant depth, almost as constant, in fact, as that of the inner cell-lamina, whereas the outer layer of granules exhibits differences in depth in individual cases, which are as readily determinable as are the corresponding differences that occur in the outer cell-lamina. (3) The delicate fibre-band in other parts of the cortex, which I personally regard as the homologue of the line of Gennari, is situated between the outer and middle cell-laminæ—i.e., above the granule-layer. This point is illustrated in the following rough diagram (fig. 25) of the fibre-bands of the cortex of the visuo-sensory and prefrontal regions.

I would remark that the general fibre-architecture of the cortex depends for its chief characters on the lamination and on the relative development of the cell-elements of the different laminæ. In other words, the arrangement of the fibres depends upon the position, size, and number of the pre-existing cells, and the fibres lie where there is room for them. In the fourth lamina, where cells are relatively few, a dense plexus of fibres exists and forms a definite horizontal band, the inner line of Baillarger or fourth horizontal fibre-band. This is particularly definite in the regions of association, but is usually invisible in a projection area like the visuo-sensory, since it is obscured by the immense number of projection fibres which traverse the cortex vertically to reach the line of Gennari. Between the second and third laminæ, where the larger pyramids are more or less definitely separated off from the subjacent granules, lies the third horizontal fibre-band or outer line of Baillarger, which in the visuo-sensory area contains the termini of the optic radiations and has received the name of "line of Gennari." In this region there is a great increase in the number of granules, a portion of which lies

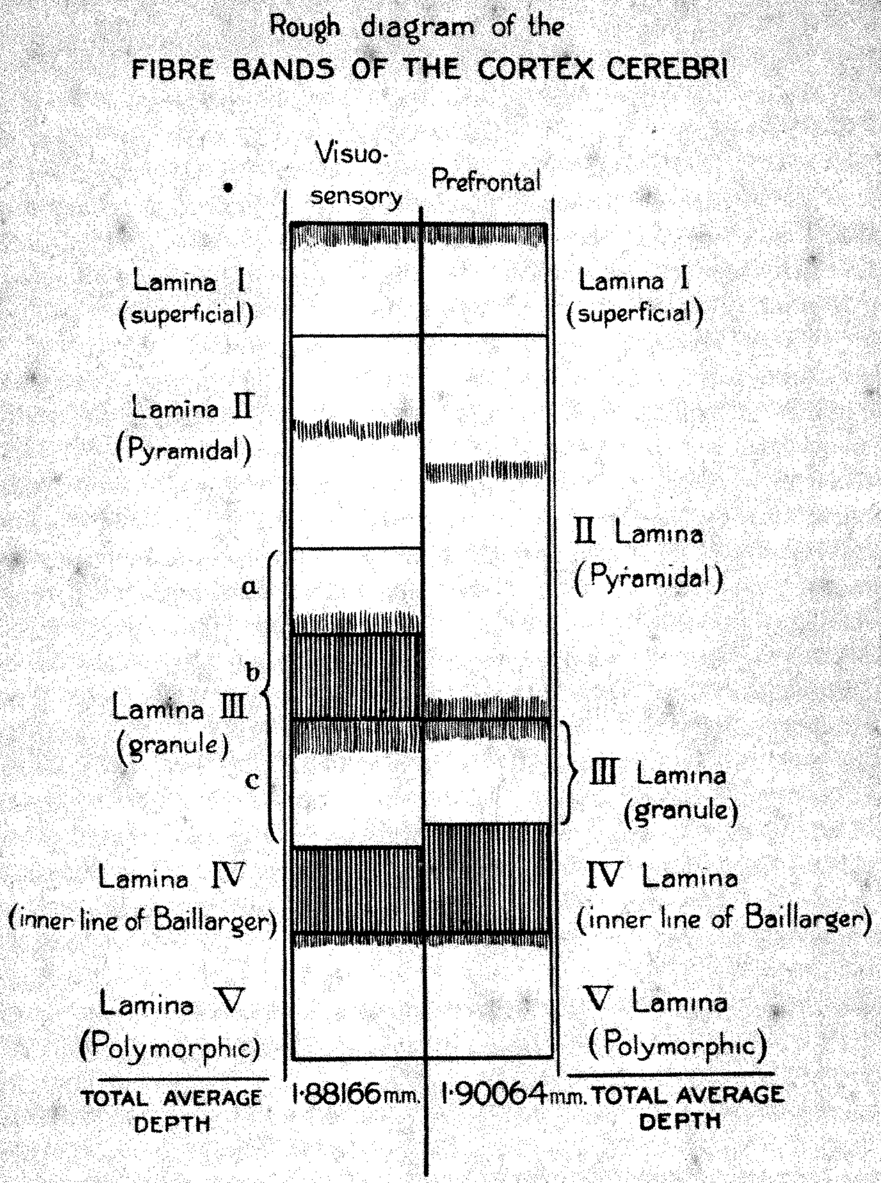


FIG. 25.

This diagram of the four horizontal fibre-bands of the cortex is not intended to show either the exact thickness of the bands, or the relative number of fibres contained in them. For the sake of simplicity, laminæ I and V are made the same depth in the two regions. Of these four horizontal bands, the outer is the *layer of tangential fibres*, the next in order is the delicate *supra-radial band of fibres*, the next is the *line of Gennari* of the visuo-sensory area *and its homologue the outer line of Baillarger* elsewhere, and the innermost of the bands is the *inner fibre-lamina of the cortex or inner line of Baillarger*.

as a separate layer above this dense fibre-band and thus indicates its functional association with the third or granule-lamina. At about the upper trisection of the second lamina lies the thin second horizontal fibre-band or super-radiary plexus, and at the surface of the cortex lies the first horizontal fibre-band or layer of tangential fibres.

The horizontal fibre-bands of the cortex are thus a secondary and accidental feature dependent on the pre-existing cell-lamination, with the subdivision of which into laminæ they should not be confused.

Before proceeding to the consideration of the prefrontal[1] region, I wish to indicate my reasons for dealing with this in detail. As I shall indicate below, the prefrontal cortex is of great functional significance, and, in fact, constitutes the physical basis of the more general processes of cerebral association. It is the last region of the cerebrum to be evolved, its degree of evolution varies in normal individuals, and it is the first region to undergo dissolution in mental decadence. It is to be expected, therefore, that such a region should possess a structure of great delicacy and high complexity, and it would seem hardly necessary to demonstrate here that this is the case.

It has, however, been definitely stated by Campbell [10], in his recent monograph, which has attracted great attention, that the prefrontal cortex is of slight structural and functional significance. He remarks: "The structural development of the 'prefrontal' cortex is exceedingly low. It presents an extreme of fibre poverty. All the fibre elements are of delicate calibre, and its association system is particularly deficient. Its cell representation is on a similar scale. The cortex is also shallow." There is no mistake, as has been suggested, with regard to the region under consideration, as a comparison of the diagrams of Campbell and of Brodmann at once indicates; and I purpose showing that the cause of the great discrepancy in the descriptions of Campbell and myself lies in the difference of method adopted. Campbell used throughout his investigations the Wolters-Kulschitzky method, which, as ordinarily employed, I regard as quite unreliable for this especial purpose. The method, on the other hand, which I adopt for the staining of the fibres of the cortex, is based on the results of a research [5] which I conducted many years ago into the chemistry of the Weigert-Pal method. I found that this process is not a specific method for the staining of medullated nerve fibres with hæmatoxylin, but is a method of dyeing fibrils which comprises three distinct operations—the mordanting of the fibrils, the formation of a lake in them by the employment of a basic dye, and, finally, the removal of the stain by oxidation from nearly every other part of the complex tissue under treatment. I compared the method with what would occur were a fabric, composed of different fibres interspersed with fine glass threads, stained by a commercial process. The glass threads would refuse the mordant and consequently the lake, whereas the fibres would retain the stain. In the case of human tissue, the more highly metabolic elements represent the fibres, and the more fixed and lowly metabolic elements the glass threads. Further, the process is applicable to any, and not solely to nervous, tissue—e.g., kidney, involuntary muscle, &c., form beautiful low-power specimens. The mordanting of the tissue is the most important process, and osmic acid, iron alum, and ammonium molybdate (used separately or consecutively) are the strongest mordants. My results were independently and almost simultaneously confirmed by Herrick [12], and the method has for years been successfully applied to the staining of cortical fibrils by G. A. Watson [24], who, in 1903, published details of the special mode of employment necessary to display them, and of the difficulties which attend the obtaining of positive results. The usual Weigert-Pal methods, however, are still in general use, and by means of these it is practically impossible even imperfectly to stain the delicate fibrils of the prefrontal cortex.

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[1] The "prefrontal region" may be defined as the anterior portion of the frontal lobe, including the mesial marginal gyrus but not the orbital surface. Its extent varies greatly in different brains. Its approximate fissural limitations are as follows: It is bounded laterally by the *inferior frontal sulcus;* and, anteriorly, by the *fronto-marginal sulcus* of Wernicke (sulcus transversus anterior) at its inner part, and the *lateral fronto-marginal sulcus* of Eberstaller at its outer part. The convolutional pattern of the prefrontal region is approximately as follows: The *fronto-marginal sulcus* of Wernicke is often duplicated or triplicated, and that of Eberstaller may or may not have a *sulcus radiatus* above it. The anterior parts of the *superior and inferior frontal sulci* pass forwards over the prefrontal region. Between these is the *sulcus frontalis medius* of Eberstaller, which is often described as a sagittal and frequently detached part of the *fronto-marginal sulcus.* This sulcus is inconstant and often broken into pieces, and it frequently joins the *superior frontal sulcus.* In good brains it is well developed and lies in the centre of a large and complex *middle frontal gyrus.* Lastly, near the midline, parallel to the *superior frontal sulcus*, is the anterior portion of the inconstant and imperfect *sulcus mesialis* of Cunningham.

The prefrontal region as here defined approximately corresponds with the "prefrontal" cortex of Campbell (fig. 3), and with the corresponding histological region of Brodmann (10 of fig. 7). It is the site of the anterior centre of association of Flechsig (fig. 1). It is the chief focus of the sub-evolution and dissolution of the cerebrum which occur in amentia and dementia.

Before dealing with the prefrontal cortex, I will now rapidly show a few slides illustrative of the results of the method I advocate:—

Fig. 26.—Medulla oblongata of frog, low power. Fig. 27.—Medulla oblongata of frog, high power. These two specimens are introduced in order to show the results of the method when applied to nervous tissue which is notoriously difficult to stain.

Fig. 28.—Posterior root ganglion of cat. This specimen demon-

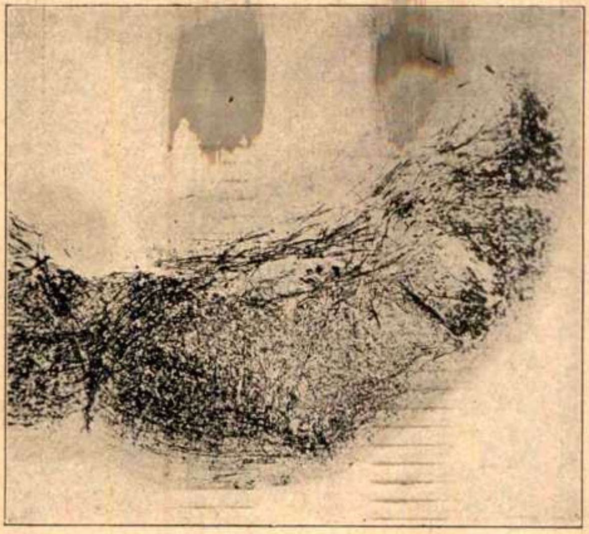


FIG. 26.

Thirty-seven diameters. Medulla oblongata of the frog. Mordanted with iron alum. The raphe is shown on the left of the figure. The nucleus near the upper surface at the outer trisection is shown, more highly magnified, in the next figure.

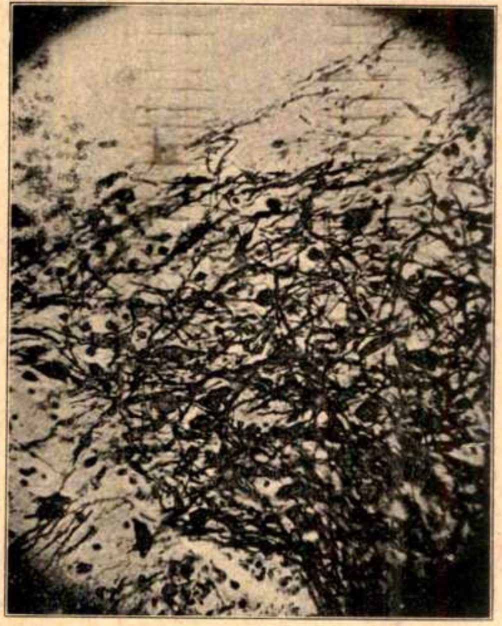


FIG. 27.

One hundred and fifty-seven diameters. Medulla oblongata of the frog. Mordanted with iron alum. The figure shows the nucleus referred to in fig. 26. The nerve-cells and the coarse and fine fibres are all intensely stained. The bodies in the upper part of the figure near the left-hand margin are red blood discs.

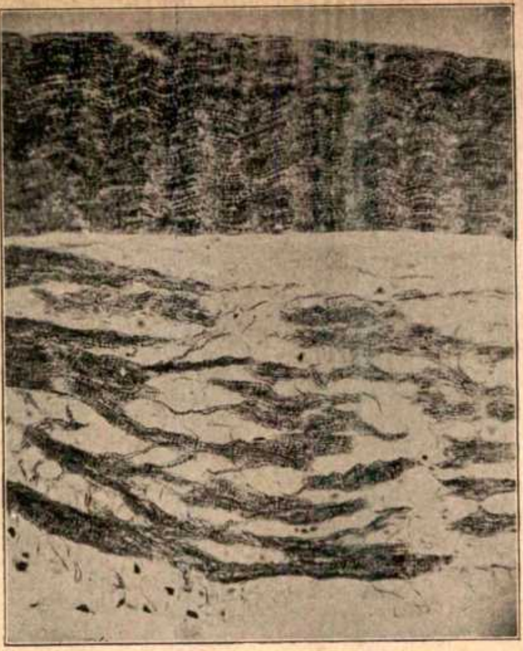


FIG. 28.

Thirty-two diameters. Longitudinal section of the posterior root ganglion of the cat. Mordanted with ammonium molybdate. The figure illustrates the results of the application of the method to ordinary coarse nerve fibres.

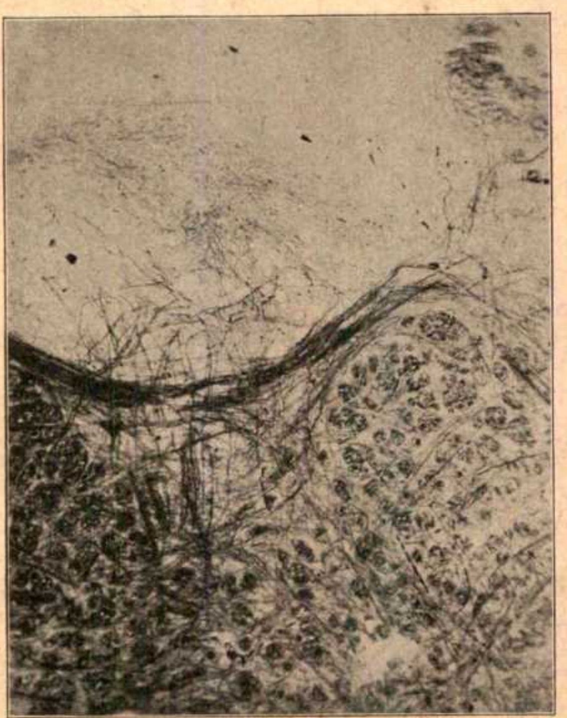


FIG. 29.

Fifty-eight diameters. Nucleus of origin of the hypoglossal nerve of the cat. Mordanted with ammonium molybdate. The figure shows the results of the application of the method to nervous tissue containing a plexus of delicate fibrils.

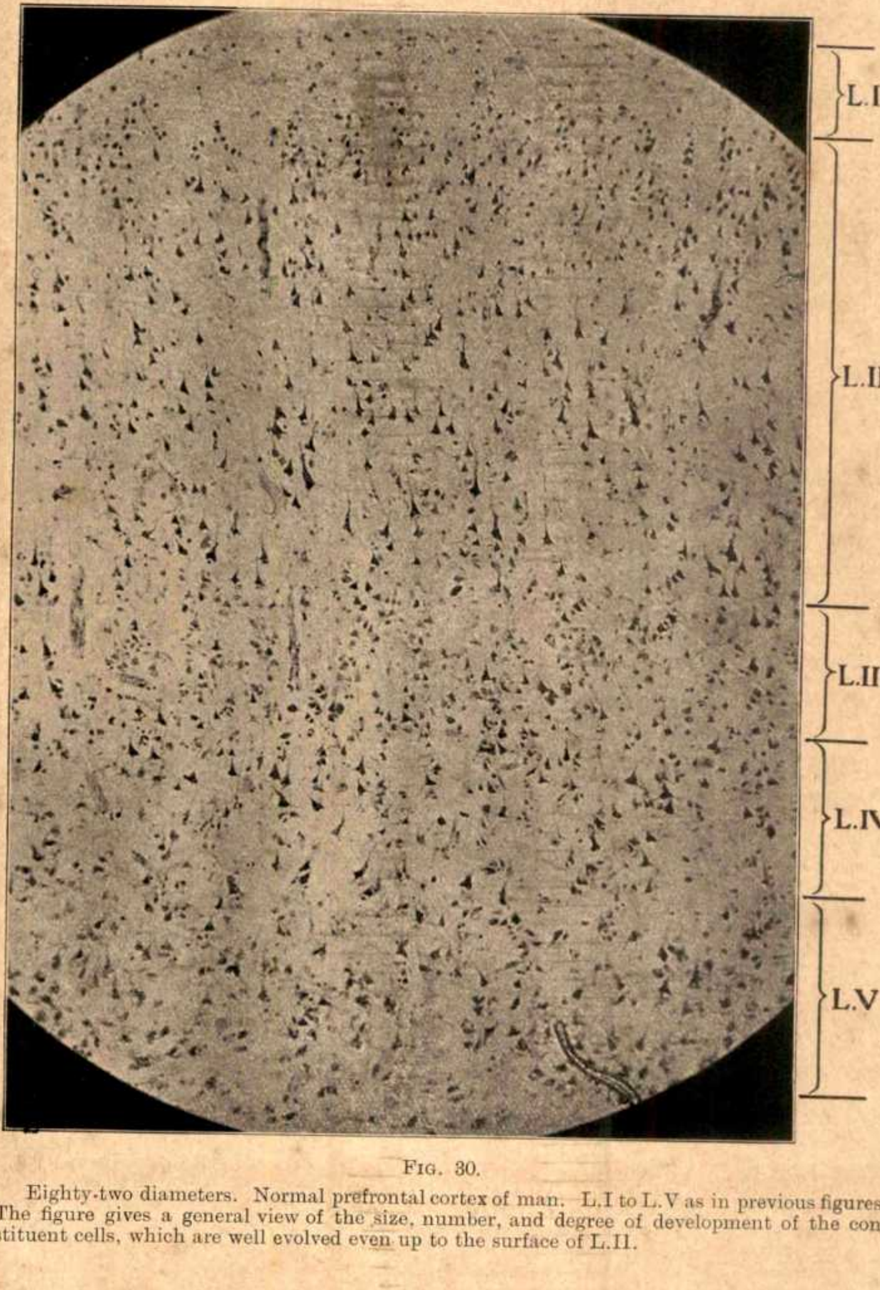


FIG. 30.

Eighty-two diameters. Normal prefrontal cortex of man. L.I to L.V as in previous figures. The figure gives a general view of the size, number, and degree of development of the constituent cells, which are well evolved even up to the surface of L.II.

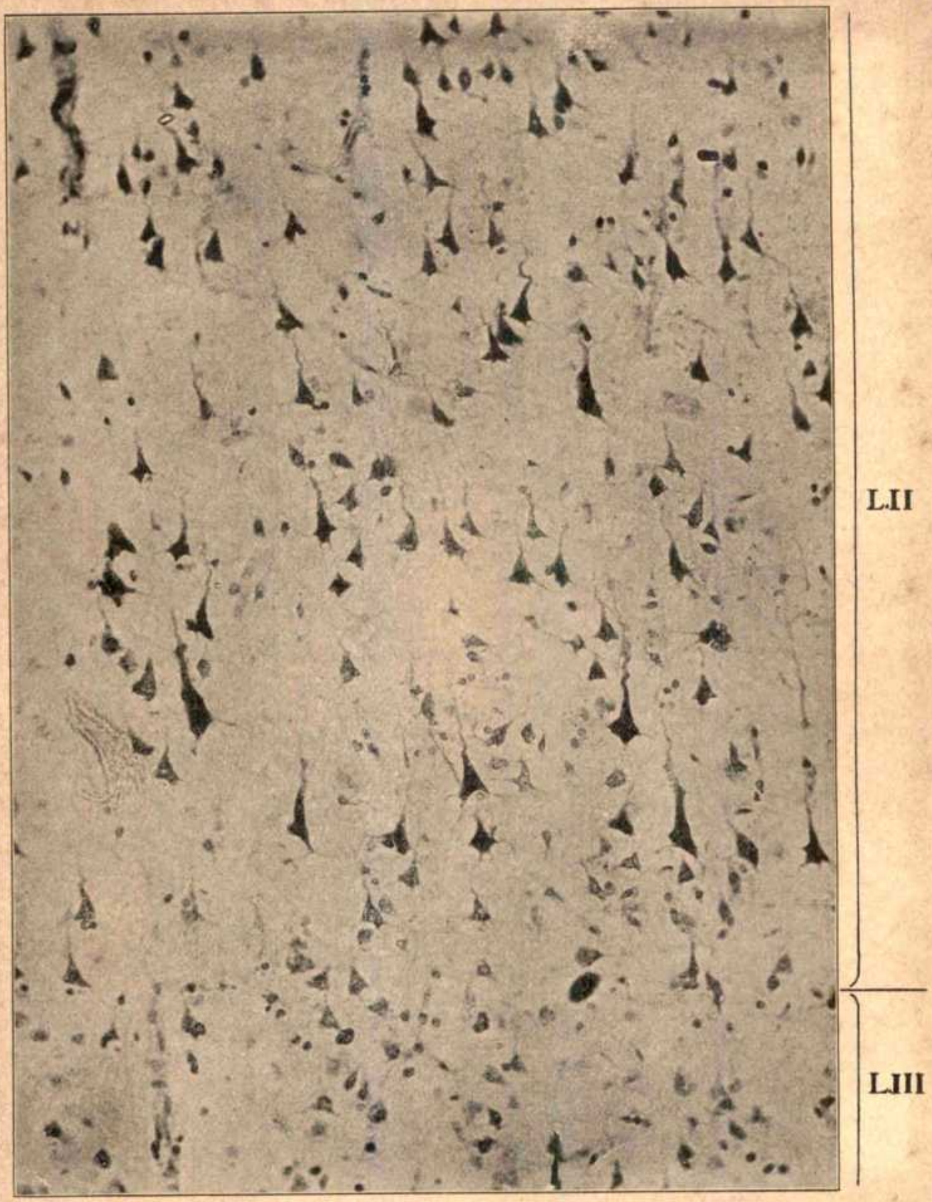


FIG. 31.

Two hundred and eleven diameters. A portion of the preceding microphotograph more highly magnified. L.I to L.V as in previous figures. The figure shows the lower two-thirds of L.II, and the upper portion of L.III. The well-known wavy appearance of the apical processes of certain of the cells, which is apparently due to some defect in the process of hardening, is well shown. Sections presenting this appearance are unsuitable for the purposes of measurement, however perfectly they may be stained.

strates the results of the application of the method to ordinary coarse nerve fibres.

Fig. 29.—Nucleus of the twelfth nerve: Cat. This photograph, on the other hand, shows the results of the application of the method to nervous tissue containing a plexus of delicate fibrils.

I will now pass to the consideration of the structure of the prefrontal cortex, and I would remark that the specimens from which I have prepared the photographs were stained by G. A. Watson, and thus afford independent testimony with regard to the method and its results. As I have already remarked, the prefrontal cortex exhibits the same lamination as the visuo-psychic zone—namely, an outer fibre-lamina, outer and middle cell-laminæ, an inner fibre-lamina, and an inner cell-lamina.

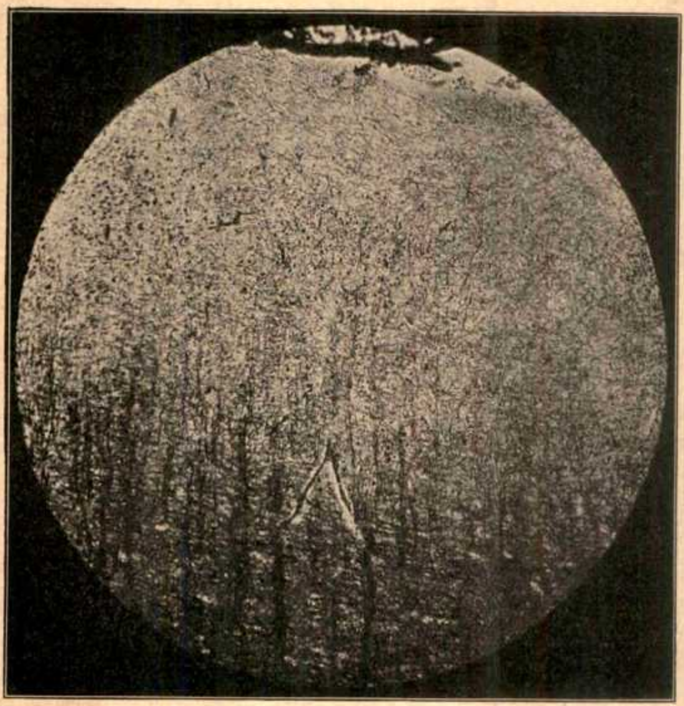


FIG. 32.

Forty-eight diameters. A lower power microphotograph of the greater part of the depth of the cortex. The succeeding figures (figs. 33 to 36) show, from above downwards, parts of the cortex under a higher power; and a portion of the vessel which is seen below the centre of the figure appears in fig. 35.

The photograph on p. 65 (fig. 30), which includes the greater part of the depth of the cortex, gives a general view of the size, number and degree of development of the constituent cells, which are well evolved even up to the surface of the second lamina.

In the next (fig. 31), which is more highly magnified, the general appearance of the cells of the lower part of the pyramidal lamina is shown. These specimens exhibit no evidence of cell paucity. They show the well-known wavy appearance of the apical processes of certain of the cells, which is apparently due to some defect in the hardening

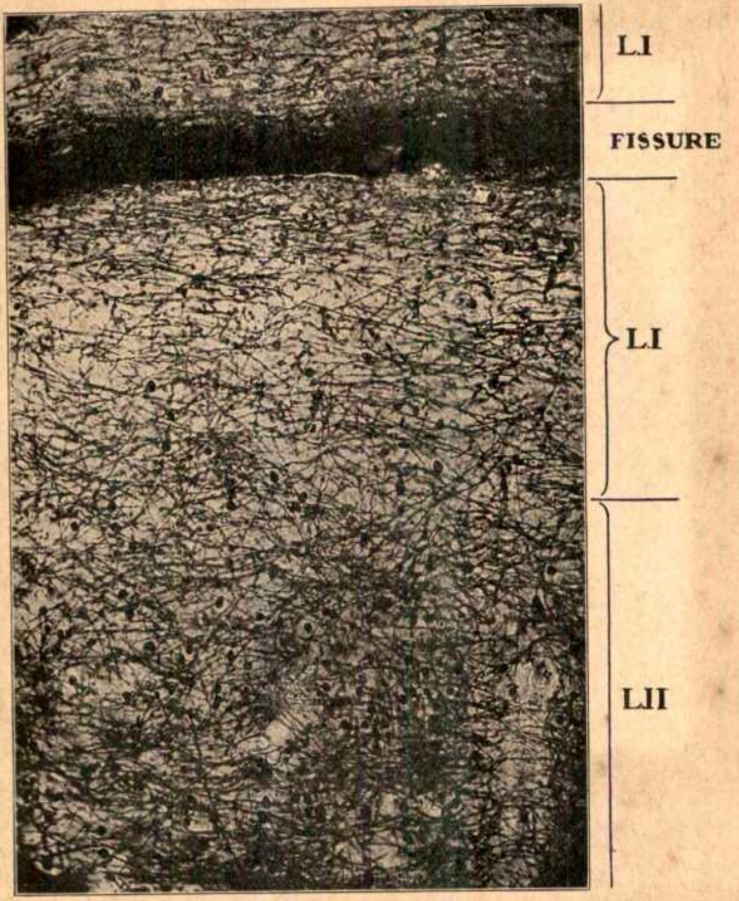


FIG. 33.

One hundred and sixty-five diameters. The figure shows the great wealth of fine fibrils present in L.I and in the upper part of L.II.

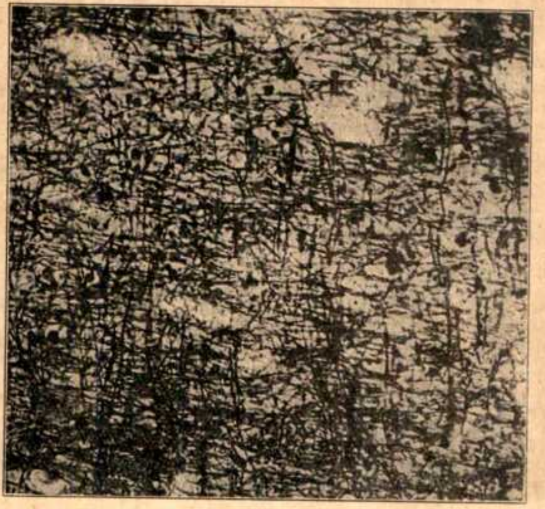


FIG. 34.

One hundred and sixty-five diameters. The figure shows the fibrillar meshwork which exists at the junction of L.II and L.III. In the upper half, the delicate horizontal feltwork above the granules may be seen.

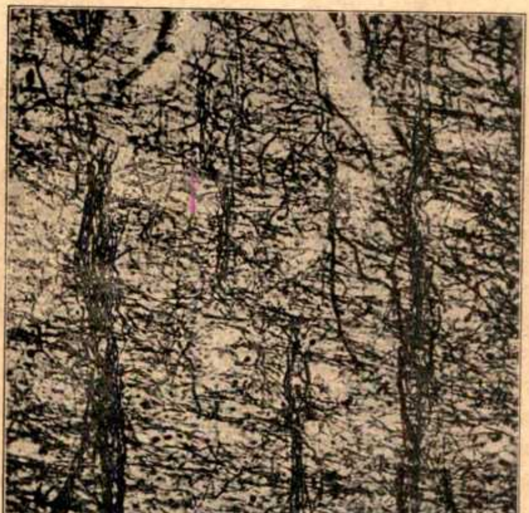


FIG. 35.

One hundred and sixty-five diameters. The figure shows the fibrillar meshwork between the upper parts of the columns of Meynert. At the top of the figure is shown the lower part of the Λ-shaped vessel seen in fig. 32. To the left of the centre may be seen one of the relatively coarse vertical fibres which are present in considerable numbers.

process. For this reason I never employ sections, which exhibit this appearance, for the purposes of measurement.

I will now conclude this lecture by giving a few illustrations of the fibre architecture of the prefrontal cortex.

In the low-power photograph (fig. 32) the greater part of the depth of the cortex is included, and I shall show photographs of portions of this rom above downwards.

The first of these (fig. 33) shows the outer fibre-lamina or superficial layer. The fibrillar complexity is evident. In the lower part of the figure is seen the outermost part of the second lamina or pyramidal layer, and the fibre wealth is very clear.

The next (fig. 34) is taken at the junction of the second and third laminæ, and shows the delicate feltwork above the granules.

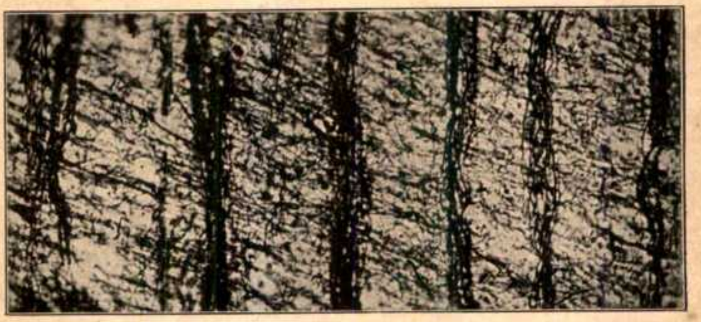


FIG. 36.

One hundred and sixty-five diameters. The figure shows six of the columns of Meynert, together with the feltwork of fibres between them.

The next photograph (fig. 35) gives the appearance of the cortex in the upper part of the columns of Meynert and includes a coarse nerve fibre which was visible in the low-power photograph.

The final specimen (fig. 36) is taken lower down, and shows the columns of Meynert.

In view of these photographs it is impossible to deny the great complexity of the fibre architecture of the prefrontal region; and I may add that John Turner [22], in 1906, almost simultaneously with the appearance of my paper on this subject, also combated the statements of Campbell and remarked that the prefrontal region, treated by a special method of his own, shows a wealth of intercellular fibrils probably greater than in any other region of the cortex.

CHAPTER V.

Intracranial Abnormal and Morbid Appearances in Mental Disease—Generalization of Amentia and Dementia.

Before proceeding to the consideration of the results of my investigation of the cortex cerebri of certain selected cases of insanity, I propose to refer briefly, from the clinico-pathological aspect, to certain abnormal and morbid appearances which are exhibited by the intracranial contents of the subjects of mental disease.

With few exceptions, which are unimportant in this connexion, such abnormal and morbid appearances have long been well known, but, at any rate up to the time when I published my first paper on the subject, no attempt, so far as I am aware, had been made to correlate these with any special symptomatology, and they had been described as common concomitants of the more chronic forms of insanity. Of these abnormal and morbid appearances, the more important are abnormal structure or wasting of the cerebrum, thickening and opacity of the pia-arachnoid, disease of the cerebral vessels, excess of intracranial fluid, subdural deposit, thickening of the dura mater, and abnormalities of the cranial vault.

In two consecutive series of 200 and 233 cases of mental disease [7], from which cases of general paralysis and special examples of gross lesion, &c., were excluded, and in which both the clinical and the post-mortem aspects presented by them were systematically recorded, I was able to determine that an important correlation existed between these.

The cases of the first series were divided pathologically into five convenient, though artificial, groups, namely:—

(1) Cases with or without abnormal, but without morbid, appearances.

(2) Cases with slight morbid appearances—namely, slight excess of intracranial fluid, slight thickening of the pia-arachnoid, which stripped rather more readily than natural, and slight or no cerebral wasting.

(3) Cases with morbid appearances of moderate grade—namely, intracranial fluid to the level of the tentorium, moderate thickening of the pia-arachnoid, which stripped readily from the hemispheres, and a moderate degree of cerebral wasting.

(4) Cases with marked morbid appearances—namely, intracranial fluid well above the tentorium, much thickening and opacity of the pia-arachnoid, which stripped very readily from the cerebrum, much wasting of the cerebrum, and, as a rule, marked disease of the cerebral vessels.

(5) Cases with gross morbid appearances—namely, very definite excess of intracranial fluid, much thickening and opacity of the pia-arachnoid, which stripped like a glove from the hemispheres, gross wasting of the cerebrum, and almost invariable affection of the cerebral vessels, which were usually greatly diseased.

On comparing the cases, from the aspect of symptomatology, with the post-mortem records, it was at once evident that these five groups corresponded, with a few exceptions which were readily explicable, with five artificial clinical groups, namely:—

(1) Cases without dementia.

(2) Cases with appreciable dementia.

(3) Cases with dementia of moderate grade—i.e., the ordinary chronic lunatic with moderate dementia.

(4) Cases of severe dementia.

(5) Cases of gross dementia.

Exactly similar results followed the study of the second and confirmatory series of cases, and I have since, for some years, been accustomed to prognose intracranial appearances with certainty, in all but the rare cases in which I have been uncertain as to the clinical state of the patient.

For reasons which I shall very briefly lay before you, I was hence able to subdivide cases of mental disease into two types—namely, (1) cases which, from the macroscopic post-mortem aspect, exhibited abnormal, no abnormal, no morbid, or slight morbid appearances; and (2) cases which exhibited morbid appearances of any grade of severity, and, in some instances, abnormal appearances also.

The former group from the clinical aspect I class under the term "amentia," which I employ to connote *the mental condition of patients suffering from deficient neuronic development;* and the latter under the term "dementia," which I use to signify *the mental condition of patients who suffer from a permanent psychic disability due to neuronic degeneration following insufficient durability.*

The subjects of amentia, therefore, as I shall suggest from the macroscopic and prove from the microscopic aspect, suffer from a more or less marked grade of sub-evolution of the cerebrum. The chief clinical varieties of amentia are low-grade amentia, or idiocy and imbecility with or without epilepsy, and high-grade amentia, which includes "moral," unstable, and excited cases, together with cranks and asylum curiosities, recurrent cases of all types, hysteria, epileptic insanity, and true paranoia and allied cases.

Before referring to the question of dementia, a further explanatory description of this mental condition is necessary. The word "dementia," and particularly the word "demented," are employed by alienists for different purposes. Some speak of demented patients recovering, others regard almost any reasonably quiet chronic case as demented, and others, again, deny the possibility of in any way whatever correlating psychic states and material conditions of the brain, and regard such as a form of confusion of thought. It is therefore necessary, in addition to defining the term, to indicate the commoner symptoms which are presented by patients suffering from dementia.

These, in brief, are as follows:—

General dulness and apathy, a loss of initiative, and an indifference to their surroundings; a marked degree of stereotypism of all the mental processes, and an inability to learn new acquirements; a mechanical method of performing known acquirements, a general stupidity and inability to understand when an attempt is made at correction of any kind, and a tendency to revert to accustomed modes of speech and action; finally, there is a tendency to the repetition of accustomed actions which often shows that these have been performed in the entire absence of intelligent volition.

This description, I may remark, in certain respects resembles that given by numerous experimental physiologists with regard to the motor exhibitions presented by certain lower vertebrates after removal of the cerebral hemispheres, and by certain higher mammals after removal of the frontal lobes.

The subjects of dementia, as I shall indicate both macroscopically and microscopically, suffer from a more or less marked grade of involution or dissolution of the cerebrum. I group such cases into a primarily neuronic class composed of senile, presenile, mature and premature types; into a progressive and secondary class which includes senile dementia associated with gross degeneration of the cerebral vessels, and, as the result of a special study, general paralysis also; and into a class of special varieties following sense deprivation, epilepsy, and cerebral lesions.

This generalization of amentia and dementia is a gross one, and, as I shall indicate shortly, is based on the fact that cases of mental disease exhibit a lesion of the cortex of the prefrontal region of the cerebrum, which lesion, in the case of amentia, is of the nature of a true sub-evolution, and, in the case of dementia, is of the nature of a true involution or dissolution.

I would remark that the existence of amentia does not preclude the onset of dementia, that the necessary precursor of dementia is a more or less severe grade of mental confusion, and that mental confusion, when incited by temporary and removable causes—e.g., alcoholic excess—is often entirely recovered from.

Further, certain clinical indications are frequently though not constantly present which enable a prognosis to be made as to whether a given case of mental confusion is recoverable or will result in dementia. Again, it is certain that recoverable mental confusion may occur in persons possessing normal cerebra. Lastly, mental confusion followed by dementia more commonly occurs in cases with cerebra of normal or relatively normal development, though probably of deficient neuronic durability, than in cases with cerebra which exhibit some grade of sub-evolution. The generalization may, in fact, be made that the greater the grade of amentia the less is the tendency to dementia, not through a more normal durability of the cortical neurones of the former, but owing to the fact that cases of amentia so readily suffer from symptoms of mental alienation under any form of "stress" that as a rule little or no irreparable damage to the cortical neurones results.

The generalization of amentia and dementia, I may remark, does not cover the subject of special symptomatology, which, as I hope to indicate, but not yet to fully prove, depends on the degree of evolution of the cortex of the projection areas and zones of lower association of the cerebrum.

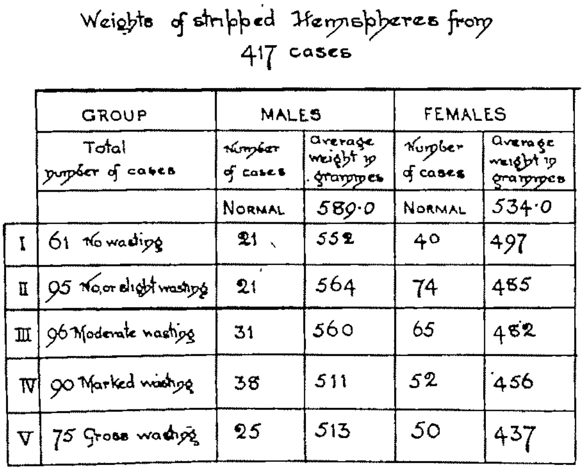
Of the abnormal and morbid intracranial appearances to which I am about to refer, the simplest, and that which is most readily determinable with accuracy, is the weight of the stripped cerebral hemispheres in the fresh state. In the following table (fig. 37) are classified under the five groups which I have indicated the weights of the stripped hemispheres from 417 consecutive and unselected cases of mental disease.

It is at once evident that the weights in all the groups are much below the average normal weight, which I have estimated from the recent statistics of Marchand [17]. I do not lay stress on this point, as Marchand's results were obtained from the brains of Hessians, although, if to the weights of Group III one added the 30 to 50 grm. which it is probable they have lost in consequence of wasting, they would come approximately up to Marchand's figures.

I would, however, indicate the obvious and important conclusion that the average weights of the hemispheres in Group III must, before wasting had occurred, have been considerably greater than those in

Groups I and II. The average weights of the hemispheres of Groups IV and V, in which severe and gross wasting had occurred, point to the same conclusion—namely, that the original weights in these groups must have been considerably greater than those in Groups I and II, since the loss of cerebral tissue in the former groups cannot average less than about 100 grm., and may be much more, in view of the large amount of intracranial fluid which is present.

I would remark that the first two groups include a small number of cases who might have recovered had they lived, and whose brain weights would tend to increase rather than to decrease the average. They also include a small number of idiots and imbeciles whose brain weights do not affect the average to an appreciable degree, some of them being much above it. The few epileptics scattered through the groups have also no important influence on the average weight. Whilst such cases might with theoretical advantage have been omitted, they have no practical influence on the average weights of the groups, and their inclusion avoids the necessity of interrupting the consecutive series. *The striking conclusion thus follows that the average brain weight of lunatics without intracranial morbid appearances is less than the original average brain weight of lunatics who exhibit such changes.*



Weights of stripped Hemispheres from 417 cases

	GROUP	MALES		FEMALES	
	Total number of cases	Number of cases	Average weight in grammes	Number of cases	Average weight in grammes
		NORMAL	589·0	NORMAL	534·0
I	61 No wasting	21	552	40	497
II	95 No, or slight wasting	21	564	74	485
III	96 Moderate wasting	31	560	65	482
IV	90 Marked wasting	38	511	52	456
V	75 Gross wasting	25	513	50	437

FIG. 87.

In other words, the cerebra of Groups III, IV, and V have fallen from a higher original level of development than that to which those of Groups I and II have attained.

I now turn to the consideration of the abnormal and morbid appearances presented by these cerebra. The question of abnormal appearances requires for its solution the microscopic rather than the macroscopic method. For example, a case of idiocy which I examined, and in which the brain, though somewhat below the average weight, appeared to the naked eye perfectly normal, except for slight simplicity of the convolutional pattern, and a somewhat decreased development of the prefrontal region, gave, when investigated by the micrometric method, general average measurements which were almost identical with those obtained from a still-born female infant. It is, nevertheless, common to meet with small, and especially with simply convoluted and abnormally convoluted, cerebra in cases belonging to the first two groups, though it is extremely rare to meet with underdeveloped cerebra of average convolutional pattern which show a macroscopic decrease reasonably comparable with the marked wasting presented by cases of severe dementia. In such cases the macroscopic decrease (apart, of course, from lesions due to abnormal development of vascular or traumatic origin) occurs in the prefrontal region of the cerebrum.

The evidences of wasting presented by the cerebra of the insane are, on the other hand, almost as fit a subject for macroscopic as for microscopic study, since, perhaps in the majority of advanced cases the tendency to decrease in cortical depth owing to neuronic loss is to some extent neutralized, especially towards the surface of the cortex, by reparative proliferation of the non-neuronic elements.

The macroscopic relationship of the degree of wasting to the degree of dementia is on the whole very exact, and the regions of relative wasting can with practice be determined with considerable accuracy. This relationship is more constant in ordinary insanity than in general paralysis, owing to the more complete removal of the products of neuronic degeneration which has occurred at death, though, when cases of general paralysis live long enough, the macroscopic wasting occupies the same sites as, and is often even more pronounced than, is the case in ordinary gross dementia.

These regions of wasting, taken generally—for individual variations occur—are as follows:—

(1) The greatest amount occurs in the prefrontal region.

(2) The wasting is next most marked in the remainder of the first and second frontal convolutions. [In dementia paralytica, Broca's gyrus should, as a rule, be included here, and (2) and (3) should follow (4).]

(3) It is perhaps next most marked in the ascending frontal and Broca's gyri, though this grade should, in many cases at least, follow (4).

(4) It is next most most marked in the first temporal gyrus and the insula, and in the superior and inferior parietal lobules. In practically all cases it is more marked in the two former than in the two latter.

(5) It is least marked in the remainder of the cerebrum (including the orbital surface of the frontal lobes), particularly the inferio-internal aspect of the temporo-sphenoidal lobe and the posterior pole of the hemisphere.

I am of the opinion that exceptions to this general order are invariably due to vascular or traumatic causes, and should therefore be excluded from the ordinary and normal wastings of dementia.

I now give figures of a number of hemispheres in illustration of the abnormal and morbid appearances which I have indicated. They are chosen on clinical grounds, being from patients in whom I was interested and with whose mental condition I was very familiar.

Group I.

Female, aged 28, single. An imbecile of moderate grade. The youngest of a family of eleven. Normal until a severe fall at the age of 3 years, after which she had fits until the age of 13. Was never at school, but when 8 to 9 years of age could converse and go errands.

Cerebrum small and simply convoluted, and very asymmetrical. R.H. (fig. 38) 372 grm.; L.H. 414 grm.

Male, aged 24, single, labourer. Insanity with epilepsy. An only child. Was in standard vii. at the age of 12 years. Had a severe fall at the age of 14 years, which was followed by fits. Mental symptoms began at the age of 18 years.

Cerebrum of average size and pattern. L.H. 593 grm. (fig. 39).

Female, aged 35, single. A drunken prostitute with over fifty convictions. Excitable, unstable, cunning and very dangerous. A terror to the nurses owing to her violence and her unfounded accusations of ill-treatment.

Cerebrum large and of rather simple pattern. L.H. 618 grm. (fig. 40).

Female, aged 30, single, servant. Heredity of insanity. Alcoholism. Previous attack. Acute mania of non-confusional type. Death from cancer of the lung nine months after admission.

Cerebrum large and of very complex pattern. L.H. 645 grm. (fig. 41).

Group II.

Female, aged 22, married, housewife. Acute mania following confinement and associated with some confusion. Died from phthisis two and a half years

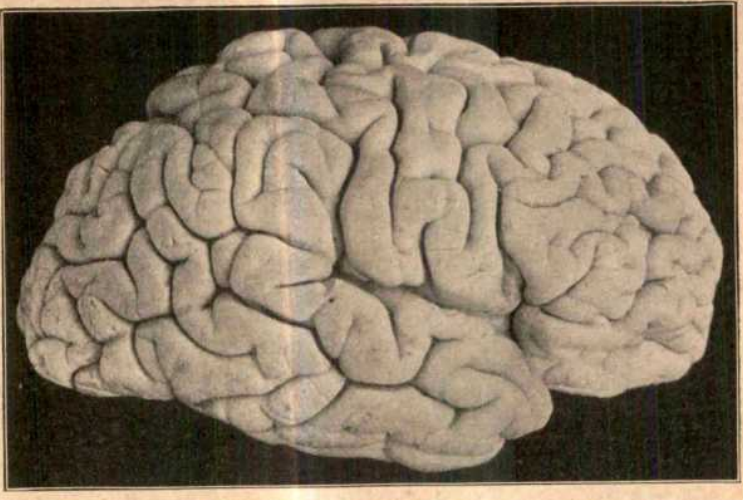


FIG. 38.

Right hemisphere of a female, aged 28. Single. An imbecile of moderate grade. Cerebrum small and simply convoluted, and very asymmetrical. R.H., 372 grm. L.H., 414 grm. No wasting. Group I.

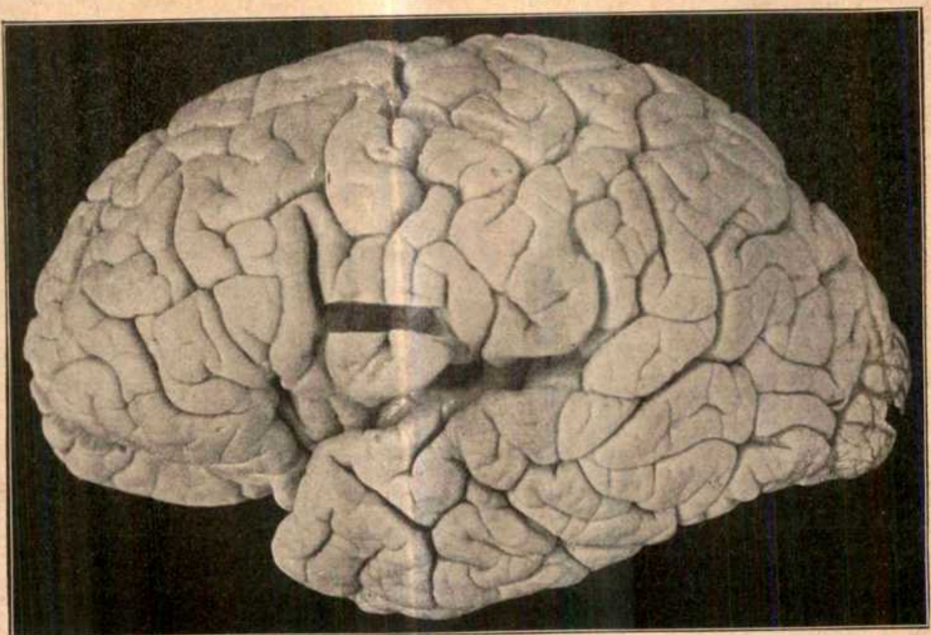


FIG. 39.

Left hemisphere of a male, aged 24. Single. Labourer. Insanity with epilepsy. Fits from the age of 14, and mental symptoms from the age of 18. Cerebrum of average size and pattern. L.H., 593 grm. No wasting. Group I.

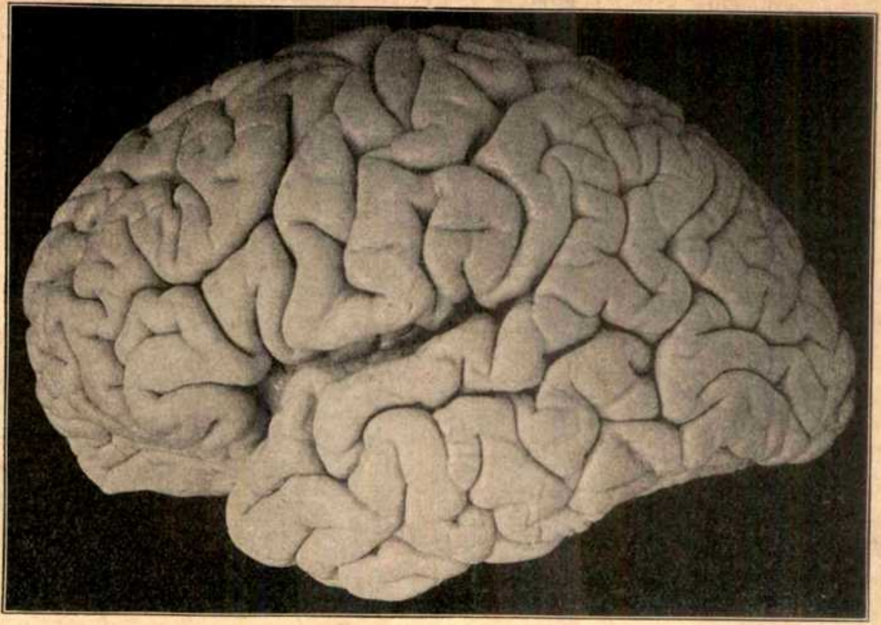


FIG. 40.

Left hemisphere of a female, aged 35. Single. A drunken prostitute with over fifty convictions. Excitable, unstable, cunning, and very dangerous. Cerebrum large and of rather simple pattern. L.H., 618 grm. No wasting. Group I.

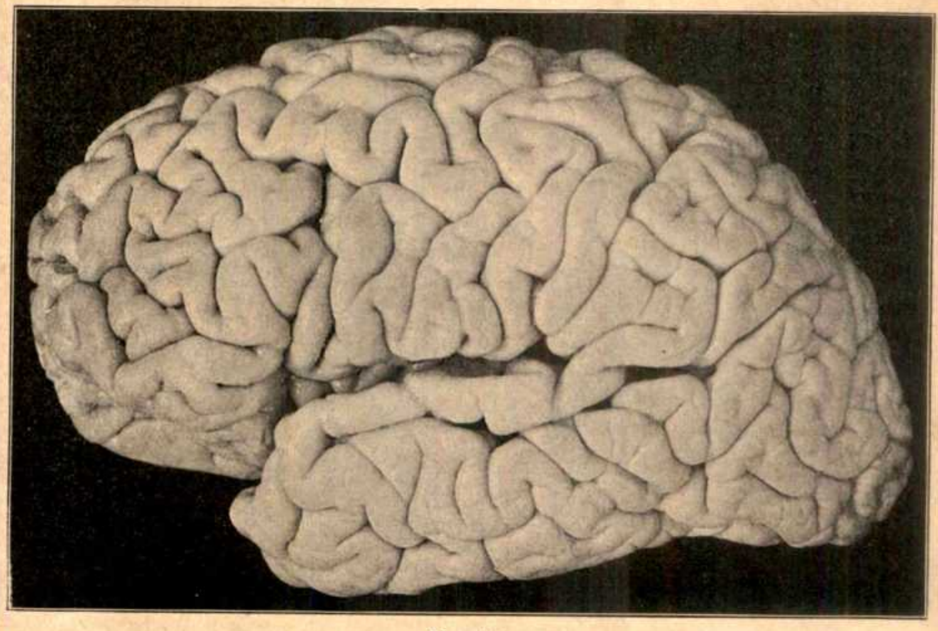


FIG. 41.

Left hemisphere of a female, aged 30. Single. Servant. Alcoholism. Acute mania of non-confusional type. Death from cancer of the lung nine months after admission (Case 7, Appendix B). Cerebrum large and of very complex pattern. L.H., 645 grm. No wasting. Group I.

after admission, and for some months before death exhibited well-marked stupor.

L.H. 495 grm. (fig. 42). Convolutional pattern was below the average in complexity. Slight intracranial morbid appearances.

Male, aged 52, married, steward. Mulatto. Intemperate. Slight dementia. Died, after a residence of 18 months, from aneurism of the aorta.

L.H. 520 grm. (fig. 43). Cerebrum below the average size, but little if anything below the average convolutional pattern. Slight intracranial morbid appearances, and slight prefrontal wasting. Moderate atheroma of cerebral arteries.

Group III-IV.

Male, aged 41, single, seaman. Duration of attack nearly 15 years. A case of chronic insanity who was at first depressed and confused. He then exhibited ideas of persecution, became grandiose, and eventually developed a moderate grade of dementia. Until he became demented he never spoke, refusing to communicate with others except by signs or by writing.

L.H. 525 grm. (fig. 44). Considerable wasting, chiefly in the prefrontal region. Several small softenings in the left hemisphere (cf. mental condition). Slight atheroma of the cerebral arteries.

Group IV.

Male, aged 61, single, schoolmaster. Duration 14 months. A case of melancholia with confusion which resulted in severe dementia.

Cerebrum large. Convolutional pattern very complex. L.H. 585 grm. (fig. 45). Marked general wasting, which is especially evident in the prefrontal region. Moderate degeneration of the cerebral arteries.

Group V.

Female, aged 78, widow, housekeeper. Duration about three years. A case of marked senile confusion. She was lost to time and place, and restless. She undressed herself. She suffered from illusions of identity. She developed gross dementia.

The cerebrum (figs. 46 and 47) had originally been probably of above the average size. R.H. unstripped, 525 grm. L.H. unstripped, 520 grm.; stripped, 480 grm. Gross cerebral wasting, which is especially marked in the prefrontal region. Some degree of asymmetry, the right hemisphere being of simpler pattern than the left. Gross degeneration of the cerebral arteries.

Gross Dementia Paralytica.

Male, aged 41. Heredity. Syphilis. Duration about two years. The case began with a long series of epileptiform convulsions and rapidly passed into gross dementia.

L.H., when partially stripped, 475 grm. (fig. 48). Wasting very extreme in the prefrontal region, and extreme in the rest of the frontal lobe, the first temporal

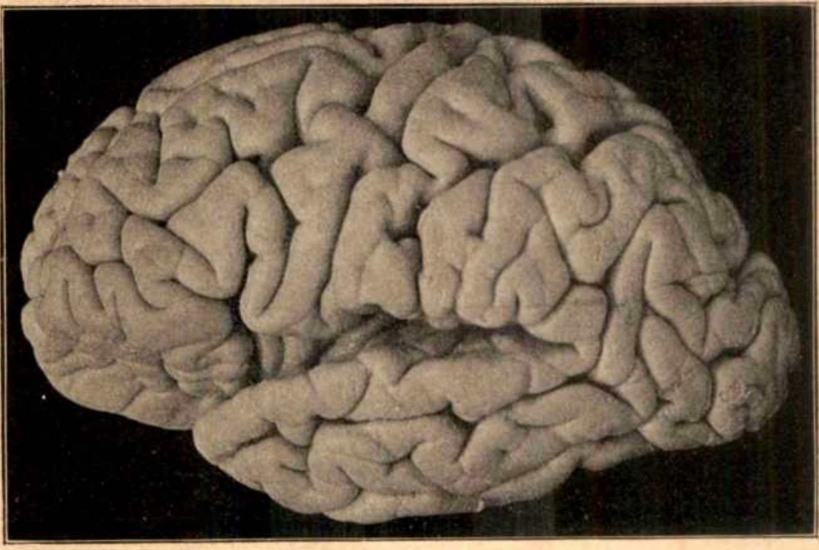


FIG. 42.

Left hemisphere of a female, aged 22. Married. Housewife. Acute mania following confinement and associated with some confusion. Died from phthisis two and a half years after admission; and for some months before death exhibited well-marked stupor. Cerebrum below the average size, and convolutional pattern below the average in complexity. L.H., 495 grm. Slight intracranial morbid appearances. Group II.

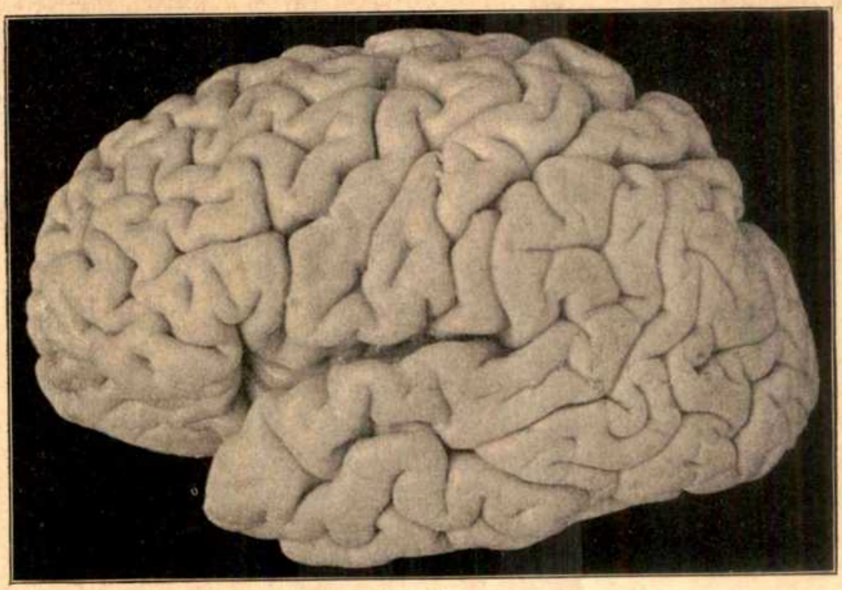


FIG. 43.

Left hemisphere of a male, aged 52. Married. Steward. Mulatto. Intemperate. Slight dementia. Cerebrum below the average size, but little, if anything, below the average convolutional pattern. L.H., 520 grm. Slight intracranial morbid appearances, and slight prefrontal wasting. Moderate atheroma of the cerebral arteries. Group II.

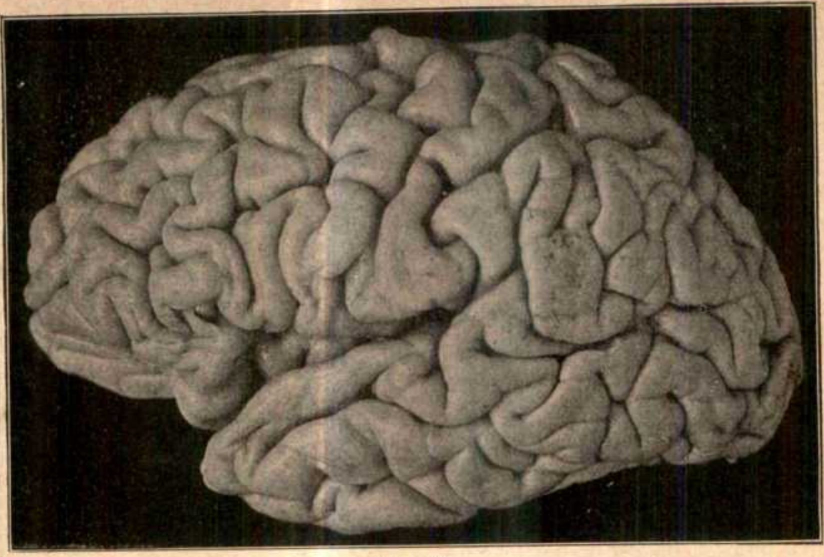


FIG. 44.

Left hemisphere of a male, aged 41. Single. Seaman. Duration of attack nearly fifteen years. Chronic insanity, with moderate dementia. Until the patient became demented he never spoke a word, refusing to communicate with others, except by signs or writing. L.H., 525 grm. Considerable wasting, chiefly in the prefrontal region. Small softenings at the hinder part of the supramarginal gyrus, at the foot of the precentral gyrus, and at the anterior extremity of the inferior frontal gyrus. Slight atheroma of the cerebral arteries. Group III to IV.

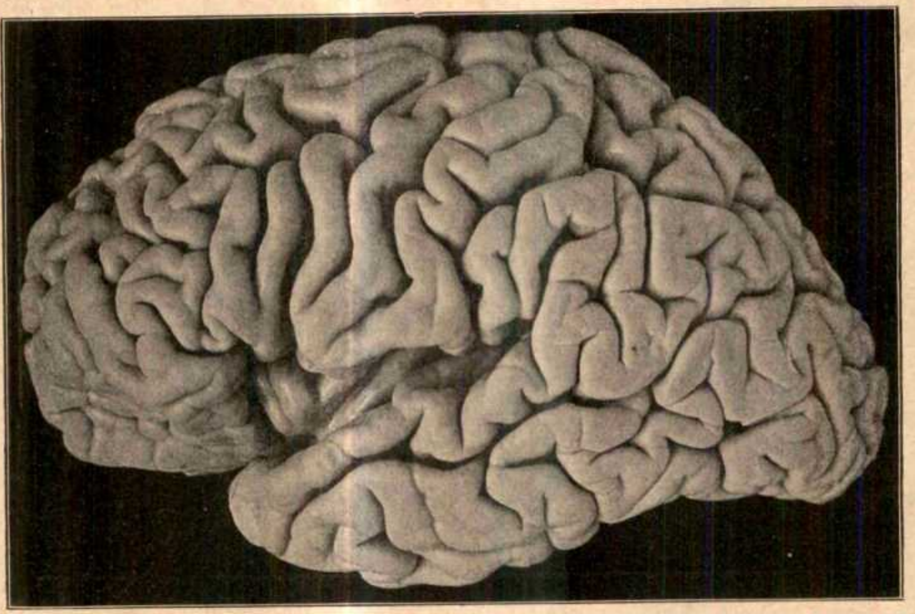


FIG. 45.

Left hemisphere of a male, aged 61. Single. Schoolmaster Duration fourteen months. A case of melancholia with confusion, which resulted in severe dementia. Cerebrum large. Convolution pattern very complex. L.H., 585 grm. Marked general wasting, which is especially evident in the prefrontal region. Moderate degeneration of the cerebral arteries. Group IV.

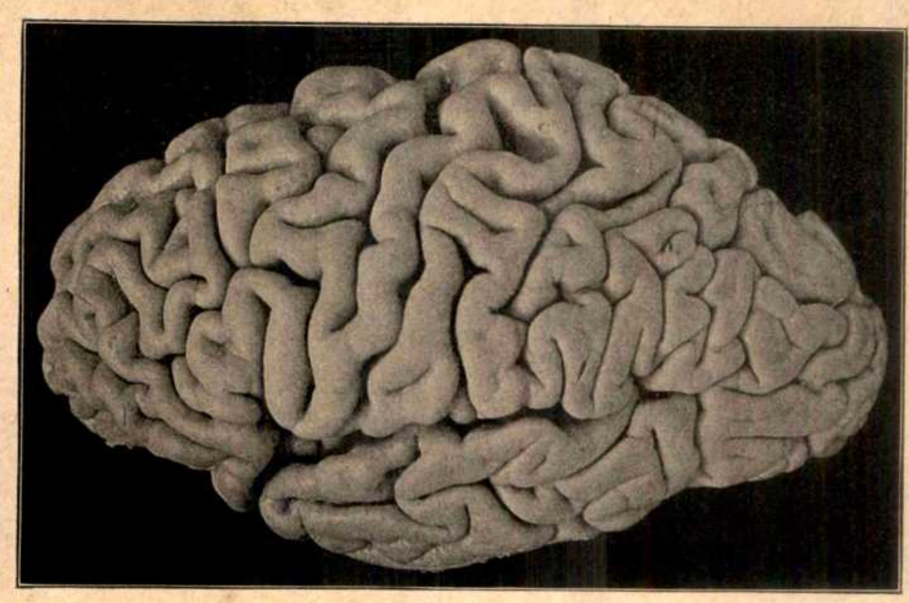


FIG. 46.

Left hemisphere of a female, aged 78. Widow. Housekeeper. Duration about three years. A case of marked senile confusion, resulting in gross dementia. The cerebrum had originally been probably of above the average size. R.H., unstripped, 525 grm.; L.H., unstripped, 520 grm.; L.H., stripped, 480 grm. Gross cerebral wasting, which is especially marked in the prefrontal region. Some degree of asymmetry. Gross degeneration of the cerebral arteries. Group V.

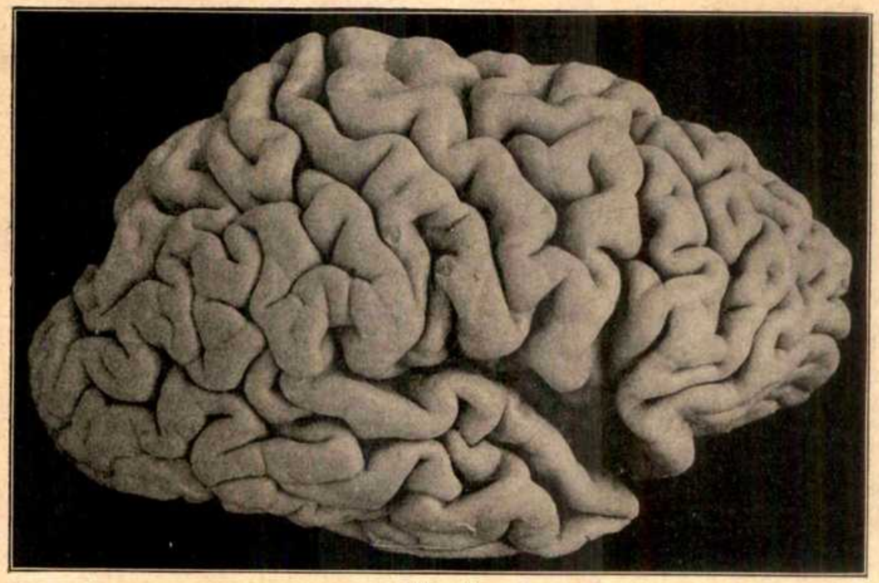


FIG. 47.

Right hemisphere of the same case. The pattern is simpler than is that of the corresponding hemisphere.

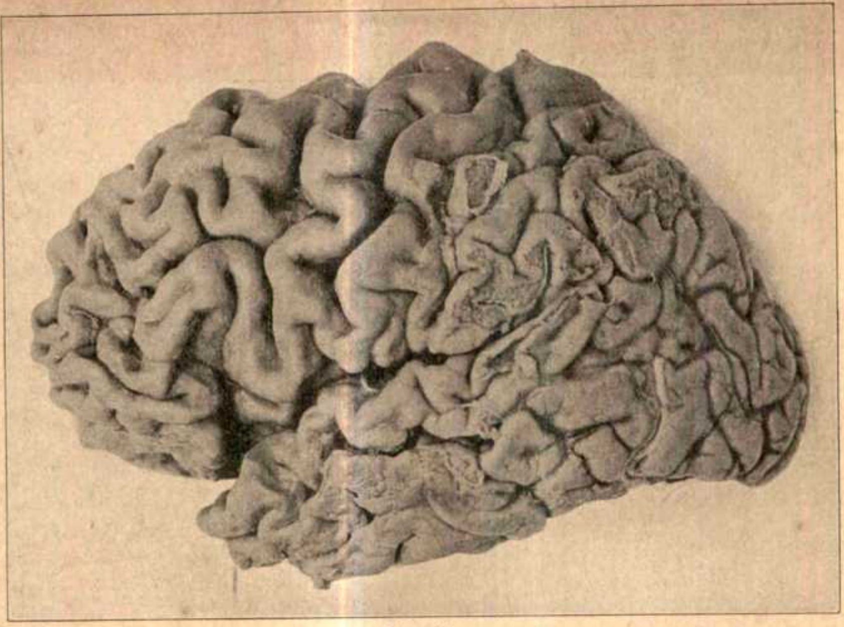


FIG. 48.

Left hemisphere of a male, aged 41. Heredity. Syphilis. Duration about two years. Gross dementia paralytica. L.H., when partially stripped, 475 grm. Very extreme prefrontal wasting. Extreme wasting of the rest of the frontal lobe, the superior parietal lobule, and the post-central and first temporal gyri. The acute degeneration, which in this particular case is indicated by the markedly adherent pia-arachnoid, is seen behind and below these regions.

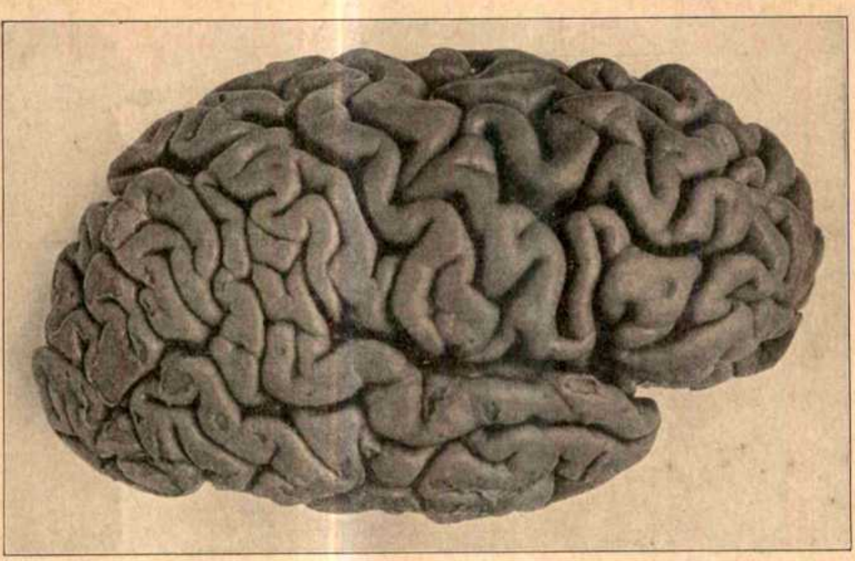


FIG. 49.

Right hemisphere of a male, aged 91. Senile decay, with relatively little dementia. Convolutional pattern somewhat above the average in complexity. R.H. 485 grm. Very gross degeneration of the cerebral arteries. The pia-arachnoid is grossly thickened over the fronto-parietal region, and adherent over the temporo-occipital. The hemisphere resembles that of Fig. 48 in the general distribution of the intracranial morbid appearances, but exhibits a marked contrast in the relative absence of cerebral wasting.

gyrus, the superior parietal lobule, and the post-central gyrus. Acute degeneration most marked in the outer part of the temporo-sphenoidal region, the inferior parietal lobule, and the preoccipital region.

Contrast Case.

Male, aged 91. Senile decay with relatively little dementia.

R.H. 485 grm. (Fig. 49). Very gross degeneration of the cerebral vessels. Piaarachnoid grossly thickened over the fronto-parietal region, and adherent over the temporo-occipital.

The case resembles the last in the general distribution of the different morbid appearances, but exhibits relatively little cerebral wasting, in this respect markedly contrasting with the previous case.

I will now draw your attention to the more important conditions which appear to influence the passage of cases from the earlier to the later groups, since, the groups being artificial, the position occupied by a particular brain at death depends on the grade of cerebral dissolution which has occurred when this ensues. Many cases remain in Groups I or II up to old age. These constitute the majority of the examples of low- or high-grade amentia of the types I have indicated. The remainder of these cases, often in consequence of severe poisoning of the cortical neurones (especially by alcohol), gradually pass into Group III, and eventually into the later groups. All the groups thus contain a number of examples of amentia.

The ordinary individual of relatively normal cerebral development is not especially prone to the onset of symptoms of mental alienation. When such a person becomes insane the limits of neuronic durability are as a rule passed, and the usual group into which the brain falls is the third, though the patient may die before it is reached. Group III, in fact, represents the position which would be eventually occupied by nearly all examples of cerebral dissolution, in the absence of the additional factor to which I am now about to refer—namely, degeneration of the cerebral vessels.

I have elsewhere shown that there is a direct relationship between the presence of degeneration of the cerebral vessels and the existence of advanced cerebral dissolution. That the latter is not a necessary consequence of the former is proved by the occasional existence of gross vascular degeneration without the co-existence of marked cerebral dissolution. Whilst both (in the absence of former syphilis) commonly occur in old age alone, neither is the necessary consequence of this, since senility, or the period at which the body-elements wear out, is an extremely elastic term, depending on their inherent resistance and on the stress to which they are subjected.

The relationship between the presence of degeneration of the cerebral vessels and the development of dementia may be thus summed up: *In a cerebrum which has begun to break down, or where degeneration has progressed to the "moderate" stage (Group III), the presence or incidence of gross degeneration of the cerebral vessels will cause rapid progress of the neuronic degeneration, with, from the clinical aspect, gross dementia.*

The contents of Groups IV and V are thus examples of progressive and secondary dementia, and are, I may remark, homologous, in my opinion, with cases of general paralysis. In both these conditions neuronic dissolution and reparative reaction of the non-neuronic elements of the encephalon occur *pari passu.* In the case of dementia paralytica the latter is more or less intense, and vascular degeneration is relatively slight; in the case of progressive senile dementia the latter is relatively feeble, and vascular degeneration is relatively severe. I would illustrate this point by a coarse analogy, comparing dementia paralytica to certain types of progressive renal cirrhosis, and progressive senile dementia to senile renal cirrhosis.

Before proceeding to the consideration of the general histology of mental disease, I would remark that certain general bodily diseases may seriously modify the macroscopic appearances presented by the intracranial contents. Of these the chief is tuberculosis, which not only so modifies the clinical picture exhibited by many cases of mental disease as often to render accurate clinical diagnosis almost an impossibility, but by producing œdema of the intracranial contents occasionally makes the determination of the group to which the case belongs a question of great difficulty.

CHAPTER VI.

Micrometric Examination of the Cerebral Cortex in Mental Disease.

I now turn to the second part of my subject—namely, the description of the results of the micrometric examination of the cerebral cortex.

The series I am about to describe includes thirty cases, of which four are normals, and twenty-six are types of mental disease which grade from the idiot on the one side to the gross dement and gross general paralytic on the other. In twelve cases the visuo-sensory and visuo-psychic regions, and in seventeen cases the prefrontal have been

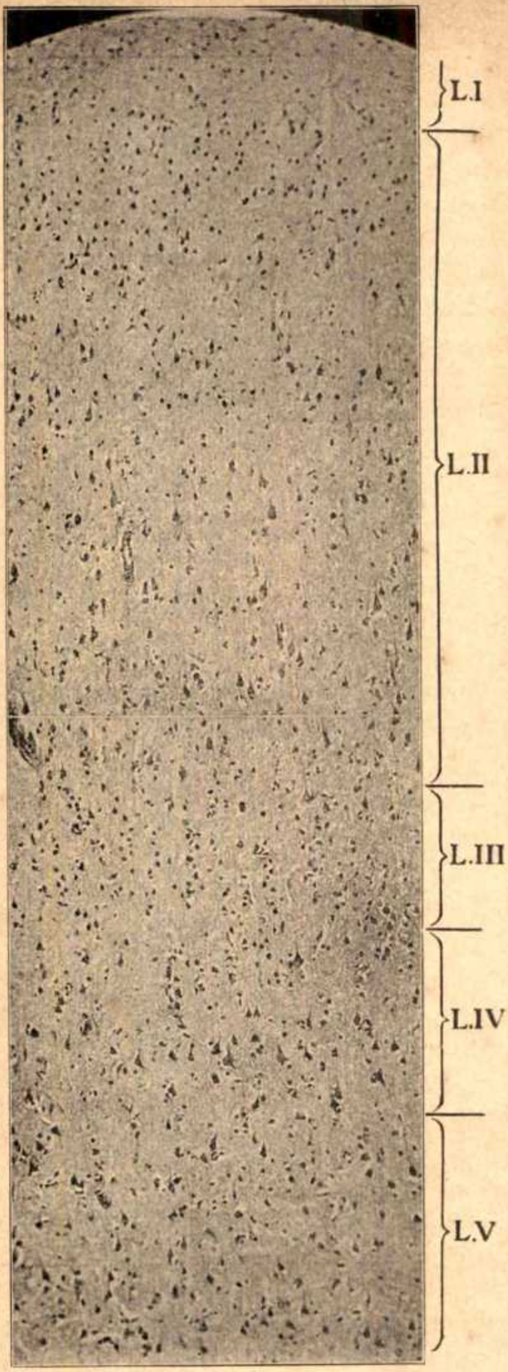


FIG. 50.

Seventy-six diameters. The prefrontal cortex of a normal adult. The magnification is somewhat less than is that of the succeeding figs. 51, 54, and 55. L.I to L.V as in previous figures.

examined and measured, whilst in one, to which I shall refer in greater detail, all these regions have been exhaustively dealt with. From the theoretical aspect, a series of cases in which all three regions had been studied would have been preferable. This, however, has not been possible, owing to the length of time occupied by the collection and examination of the material, and the great labour, and particularly the eye-strain, necessitated by such a method as that which I have been compelled to adopt. The micrometric study of the cortex by this method produces, however, such trustworthy and comparable results that the larger number of cases which I have thus been able to examine has widened the scope of the research without impairing the validity of the conclusions which result.

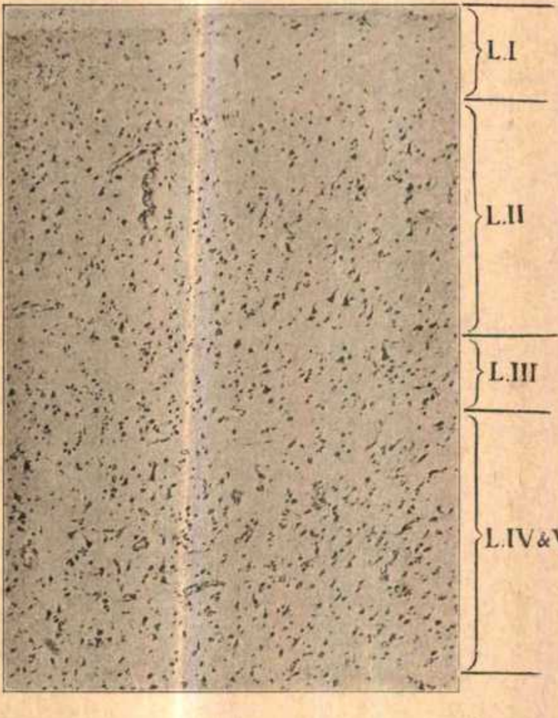


FIG. 51.

Eighty-four diameters. A case of severe imbecility (Case 14, Appendix B). L.I to L.V as in previous figures. The markedly subnormal depth, which is especially evident in L.II, may be seen when the figure is compared with fig. 50, the normal. The constituent cells are deficient in number, defective in structure, and irregular in position.

Before dealing with actual measurements, I propose to show a number of photographs of the cerebral cortex (from the prefrontal region), in illustration of the great differences which are presented by cases of different types. As I have already fully described the method of measurement, it is merely necessary to remark here that such illustrations cannot be regarded as in any way indicative of the general average measurements which result from systematic examination, since, by choosing suitable regions, it would be possible to produce the greater number of the photographs from nearly any single case in the series. In all, with the exception of the two high-power microphotographs, the magnification is the same.

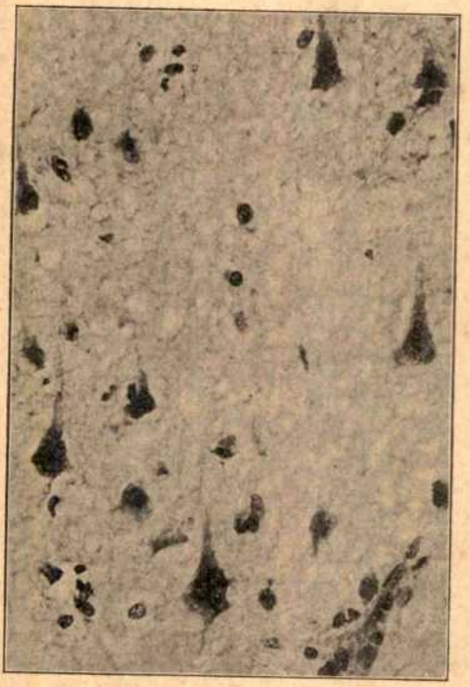


FIG. 52.

Three hundred and twenty-five diameters. Normal cells from the lower part of lamina II. The absence of the artefact seen in fig. 31 should be noted.

The first photograph (fig. 50) represents the normal appearance of the cortex. The five laminæ of which it is composed can readily be deciphered. I would particularly direct attention to the depth of the second lamina, or pyramidal layer, for comparison with the cases which follow.

In the next plate (fig. 51) is shown the cortex of a case of severe imbecility. The great decrease in depth, especially as regards the second lamina, is evident.

I now show, under a higher power, the cells of the lower part of the second lamina of this and of the preceding case. The first plate (fig. 52) shows the normal appearance of these cells, and the second (fig. 53) the stunted appearance and irregular position of the corresponding cells of the marked imbecile.

The next plate (fig. 54) shows the cortex of a well-marked imbecile of greater intelligence than the last case. The cortex is better evolved, and the larger cells are decently formed and less irregularly placed.

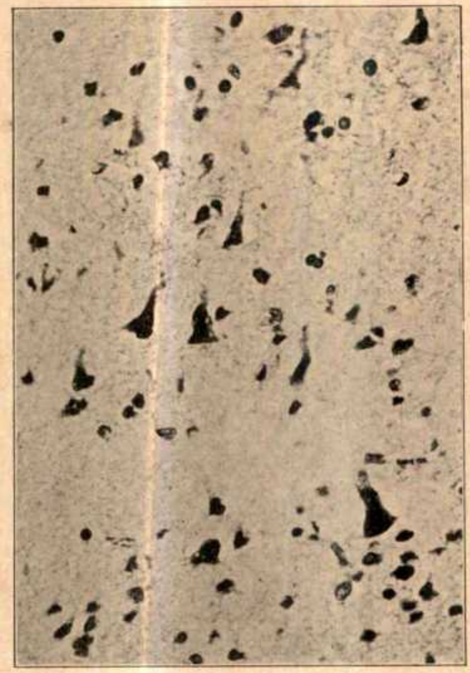


FIG. 53.

Three hundred and twenty-five diameters. Severe imbecility. The figure shows the stunted and irregularly placed cells from the lower part of L.II of the case illustrated in fig. 51. The contrast presented by the homologous cells of this and of the preceding figure should be noted.

[A plate was then shown to illustrate the cortex of an imbecile of still less marked grade.] The cortex of this case more resembles the normal, with the exception of lamina II, which is very narrow.

The next plate (fig. 55) shows practically the whole depth of the cortex of a case of gross dementia, this being very much shallower than the normal. The blood-vessels, I may remark, are both numerous and prominent when compared with a specimen of normal cortex stained by the same method. The neuroglia cells are also very numerous in a section stained to show them.

Lastly, the final plate (fig. 56) of this series shows the approximate depth of the cortex in a fœtus of six months, a stillborn infant, a case of severe amentia, a normal adult, and a case of severe dementia. Lines are drawn which include the second lamina and the third to the fifth laminæ, in order to show these more clearly.

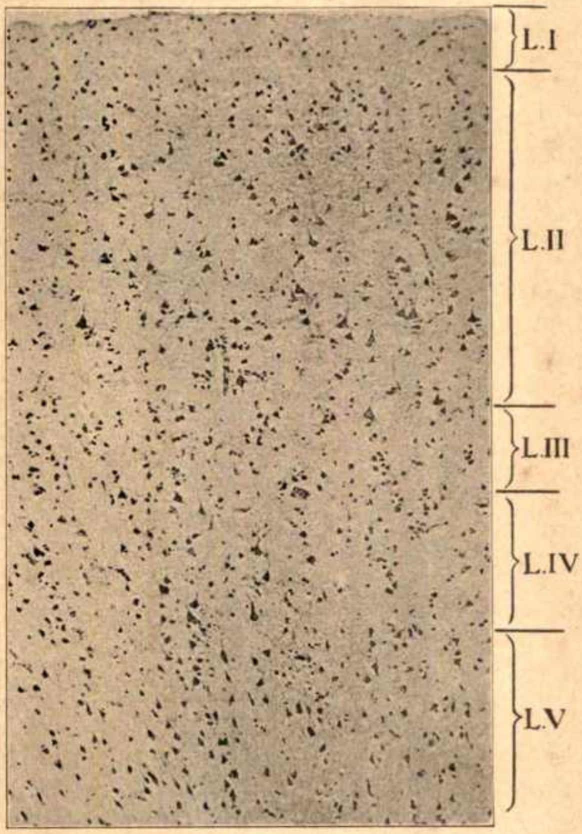


FIG. 54.

Eighty-four diameters. A case of well-marked imbecility (Case 15, Appendix B). L.I to L.V as in previous figures. The cortex is less markedly subnormal in depth than is that of the case illustrated in fig. 51, and the larger cells contained in it are less stunted in appearance, and also less irregularly placed.

I now come to the description of the results of the micrometric measurement of the cortex.

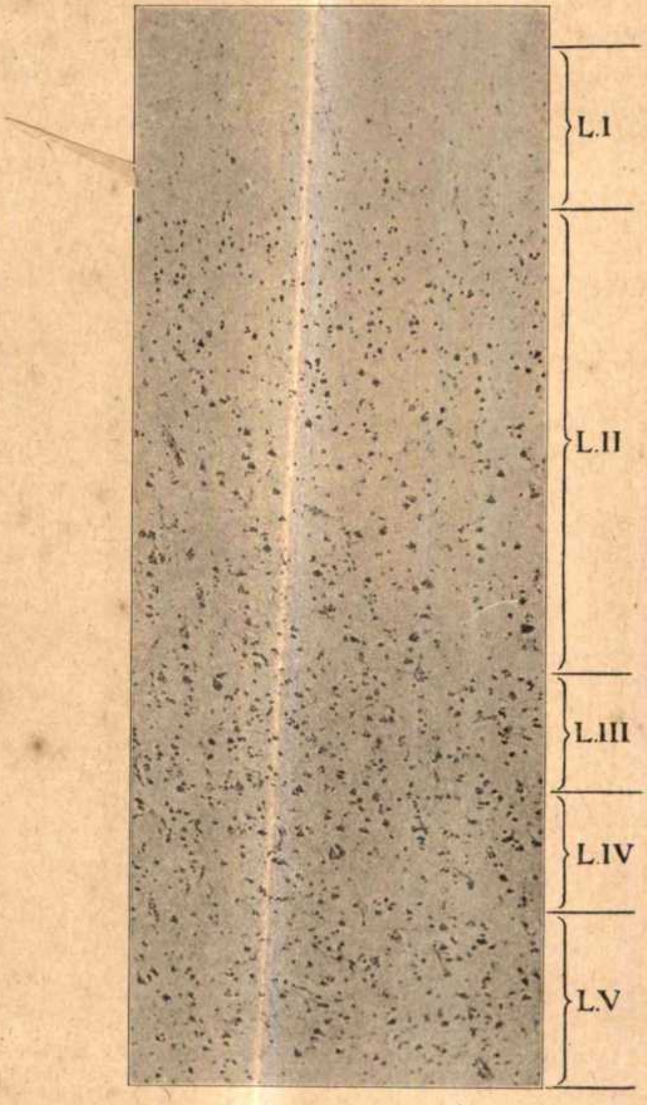


FIG. 55.

Eighty-four diameters. A case of gross dementia. (Case 29, Appendix B.). L.I to L.V as in previous figures. The cortex is much shallower than the normal. The constituent cells, particularly of L.II, are decreased in number and markedly diseased. Though this is not obvious in the figure, the blood-vessels are increased in number, and there is much proliferation of neuroglia, particularly in L.I and L.II.

I do not propose to describe the cases in detail, or to trouble you with actual figures, as I have already dealt in detail with the method I have adopted for the production of the general average measurements. I have therefore prepared the series of cases in percentages of the normal. I would remark that each case in itself represents the results of a small research, as the difficulties which have to be overcome in the preparation of vertical sections, which include a sufficient number of measurable regions, are considerable even before it is possible to begin the measurements. In several instances it has in fact been necessary to reject a likely case owing to the impossibility of obtaining measurements, for

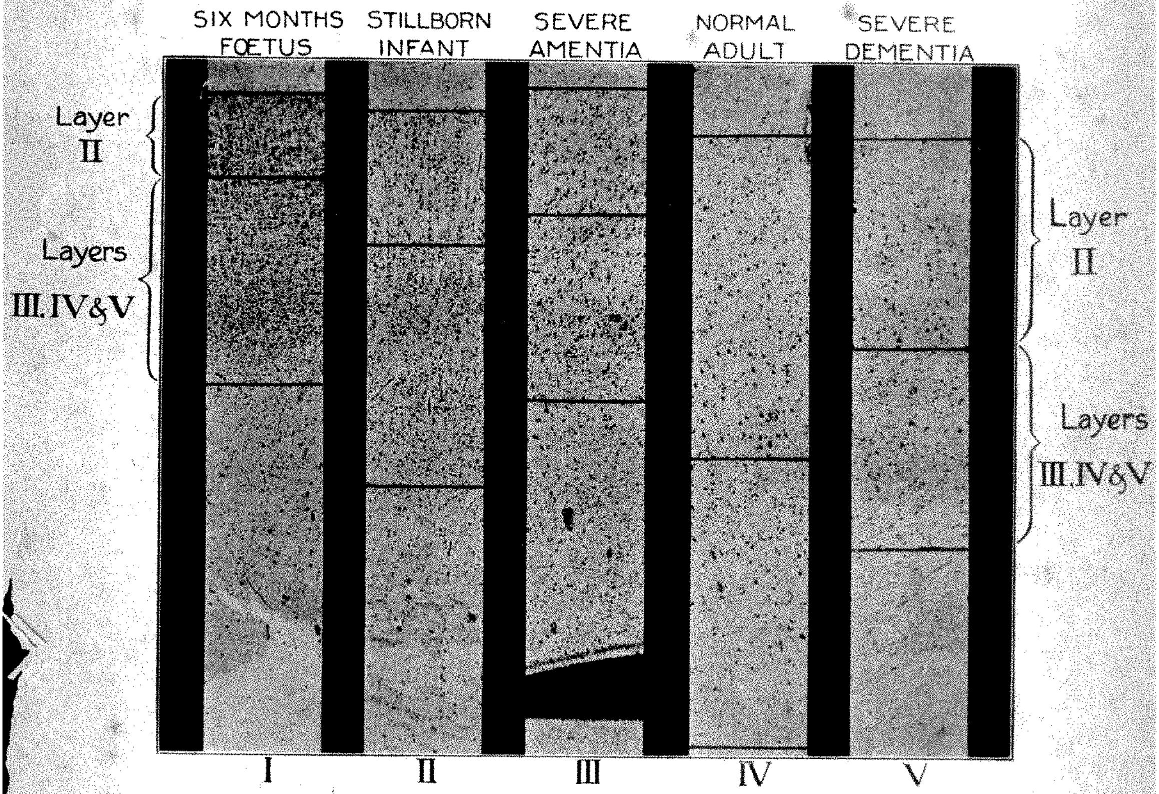


FIG. 56.

Forty-three diameters. The development of the prefrontal cortex and its condition in amentia and dementia. Horizontal lines are drawn to indicate lamina II, the pyramidal or associative lamina, and the combined III, IV, and V laminæ. A comparison of columns I, II, and IV indicates the relatively late development, and also the high degree of normal evolution of lamina II, compared with laminæ III, IV, and V. Column III indicates the marked sub-evolution of the cortex which exists in severe amentia, and column V the marked dissolution of the cortex which occurs in severe dementia.

in some cases either every block which one cuts turns out to be more or less oblique, or else some particular region, especially the flat surface or the bottom, is either oblique or missing. I may add that several cases, when ready for measurement, have been of necessity rejected owing to the existence of cerebral œdema.

On the plate (fig. 57) are shown the general average measurements of thirty cases, grouped under visuo-sensory, visuo-psychic, and prefrontal regions. The cases are numbered to allow of identification, and those placed in the visuo-sensory and the visuo-psychic groups are the same.

The cases included in each group are arranged on each side of the normals, those of amentia rising in order of mental capacity from the left-hand side, and those of dementia falling in order of grade of dementia on the right-hand side.

The visuo-sensory group includes one idiot, two imbeciles, a case of imbecility with premature dementia, two cases of recent acute insanity, and a case of simple acute mania of nine months' duration on the left-hand side of No. 8, the normal; and a case of epileptic dementia, two cases of blindness with dementia, a case of premature dementia, and a case of well-marked dementia on the right-hand side of No. 8, the normal.

The visuo-psychic group contains the same cases.

The prefrontal group includes five cases of imbecility of different grades from severe to mild, three cases of recurrent and chronic insanity without dementia, three normal cases (the central one of which, No. 23, is taken as the basis for percentages), a case of imbecility with dementia, two cases of dementia of moderate grade, one case of well-marked dementia, No. 13, which is already included in the other groups, two cases of gross dementia, and one case of gross dementia paralytica.

In the visuo-sensory region the laminæ indicated are from above down the first or superficial layer, the second or layer of pyramidal cells, the third or granule layer, which is in this region duplicated and contains in its midst the line of Gennari, the fourth or inner line of Baillarger, and the fifth or layer of polymorphic cells. It is unnecessary at present to do more than draw your attention to the markedly decreased depth of the line of Gennari in the two blind cases, Nos. 10 and 11, which detail proves that the region under consideration is the projection area for visual sensations.

In the case of the visuo-psychic and prefrontal regions the laminæ indicated are, from above downwards, the first or superficial, the second or pyramidal, the third or granule, the fourth or inner line of Baillarger, and the fifth or polymorphic.

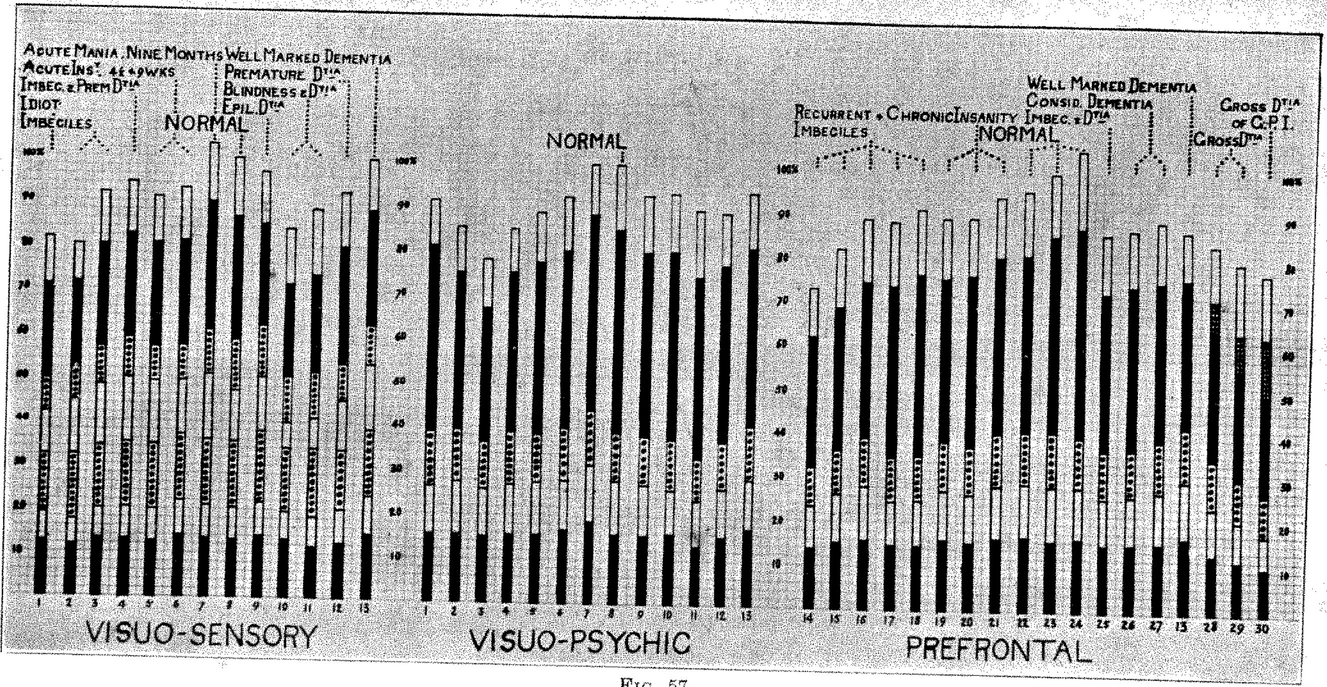


FIG. 57.

The general average depths, in percentages of the normal, of the cortices of thirty cases of various types. The actual measurements obtained from these cases, together with other details concerning them, are given or summarized in Appendix B. In the three series, the cases are grouped in each side of the normals according to the grade of amentia and dementia. The numbers at the bottom of the columns indicate the several cases. The sub-divisions of the columns from above downwards indicate the five laminæ of the cortex—namely, the outer fibre or superficial, the outer cell or pyramidal, the middle cell or granule, the inner fibre or inner line of Baillarger, and the inner cell or polymorphic. In the case of the visuo-sensory area, the receptive lamina consists of two layers of granules separated by an intermediate fibre-layer, the line of Gennari, in which terminate the optic radiations, and which is much decreased in depth in Nos. 10 and 11, the two blind cases. The figure shows that, whereas in the prefrontal region the cortex varies in depth according to the degree of amentia and dementia, no such variation occurs in the cases of the visuo-sensory and visuo-psychic regions. The further conclusions which are derived from a study of the individual cell-laminæ are indicated in fig. 58.

In the case of the gross dements, Nos. 28 to 30, in the prefrontal region, I would indicate that the depth of the outer two laminæ as measured is not an accurate criterion of the actual loss of neurones, owing to the proliferation of the non-neuronic elements which, especially in No. 30, is so marked as to a considerable extent to neutralize the results of neuronic destruction.

It is, of course, impossible to indicate the general conclusions which result from the study of these measurements without dealing with the cell layers individually. The most important result is, however, perhaps sufficiently evident to be worth pointing out.

Taking the prefrontal region first, it is obvious that in this region a definite relationship exists between the depth of the cortex of the respective cases and the degree of amentia or dementia which existed.

On the other hand, no such relationship exists in the case of the visuo-sensory and visuo-psychic regions, but an equally important conclusion may be drawn—namely, that great individual differences in depth are evident, in the former even more than in the latter; and that these individual differences not only bear no relationship to the degree of amentia or dementia which existed, but even in the case of the two regions differ in individual cases. The latter point is sufficiently evident if the first three cases are compared, since No. 1, an idiot, has poor visuo-sensory but good visuo-psychic measurements; No. 2, a well-marked imbecile, has equally poor visuo-sensory as but rather worse visuo-psychic measurements than No. 1; whilst No. 3, a moderate imbecile, shows fairly good visuo-sensory measurements but visuo-psychic which are much below those of either No. 1 or No. 2.

As the visuo-sensory region subserves the reception and the immediate transformation of visual sensations, and the visuo-psychic is concerned with associational functions which have a special visual hall-mark, it may be concluded from these measurements that marked individual differences exist with regard to both these capabilities in the case of different subjects. The measurements thus afford anatomical proof of a clinical truth, which is, I think, generally recognized, in spite of the difficulty which attends its satisfactory exhibition.

In view of the possible criticism that the ages of the patients might to some extent explain the differences in measurement, I would remark that these vary from eleven to seventy-eight years, and that I have endeavoured without success to trace even a possible suggestion of any relationship between age and measurement.

I will now pass to the consideration of the individual primary cell-laminæ—namely, the second lamina or pyramidal layer, the third lamina or granule-layer, and the fifth lamina or layer of polymorphic cells. These, as abstracted from the last plate, I now show on fig. 58.

It will be convenient to consider first all the three regions together from the general aspect, and then to deal with each region individually.

In the case of the fifth lamina, it is evident that its depth in the visuo-sensory region is considerably less than—namely, about $\frac{13}{16}$ of—its depth in the visuo-psychic and prefrontal regions, whereas it is of exactly the same depth in the two last. Further, in the visuo-sensory region seven of the twelve abnormal cases reach to or above the normal line, whereas in the visuo-psychic region only five of twelve, and in the prefrontal region but three of fifteen, excluding, of course, the three normals, which all reach it. The fifth lamina, apart from the normal difference in depth, is thus slightly better developed in the visuo-sensory region than in the visuo-psychic, and is much better developed in both these than in the prefrontal. Further, in the prefrontal region alone does this lamina in the several cases exhibit a gradation in depth which varies according to the degree of amentia and of dementia. This lamina is the first to be evolved during the development of the cortex, and rapidly attains to approximately the normal depth. It is only reasonably below the normal depth in the prefrontal region of infants, well-marked imbeciles and gross dements, all of whom are unable to attend to the ordinary bodily functions, such as feeding, the calls of nature, &c. This lamina has been shown by G. A. Watson [25], as the result of his study of the cortex of the chief orders of the mammalia, to be the best developed and most important cell- layer of the neopallium. It is therefore impossible to avoid the conclusion that the inner cell-lamina is the fundamental cell- layer of the cortex, and that it is concerned with the performance of the instinctive in contradistinction to the receptive, the psychic, and the voluntary- psychic activities.

I now turn to the third lamina or granule-layer. This lamina is exceptionally developed and complex in the visuo-sensory area, consisting of two granule-layers with an interposed fibre-layer, the line of Gennari, in which terminate the optic radiations. In the visuo-sensory area the lower of the two layers of granules is normally much deeper than is the same layer in the visuo-psychic and prefrontal regions, whereas the upper is slightly deeper than that in the visuo-psychic, and of the same depth as that in the prefrontal region.

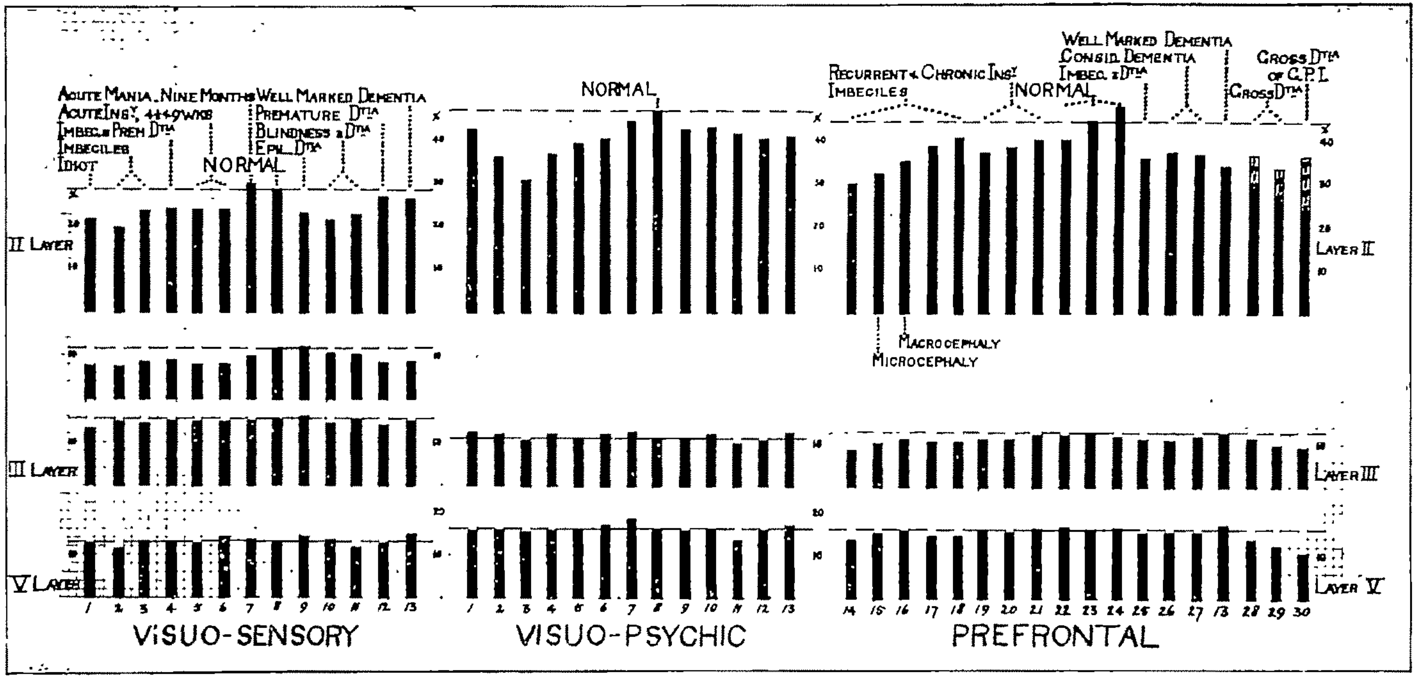


Fig. 58.

The outer, middle, and inner cell-laminæ of the thirty cases indicated in the last figure. (I) *The visuo-sensory area.* Specialization is marked, and is shown by the greatly increased depth and complexity of L.III, the middle cell- or receptive lamina, and by the much decreased depth of II, the associative lamina, and the decreased depth of L.V, the instinctive lamina. Well-marked individual variation occurs in the cases of the outer cell- or pyramidal lamina and the outer of the two granule-layers. In this region the cortex does not vary in depth according to the degree of amentia and dementia. (II) *The visuo-psychic region.* Specialization is not marked, but is indicated by the well-developed L.III, or granule-lamina, and also by certain facts of evolution mentioned in Lecture II. Individual variation is well marked in the case of the outer cell- or pyramidal lamina. The cortex does not vary in depth according to the degree of amentia and dementia. (III) *The prefrontal region.* Indications of specialization and individual variation are practically absent. All the cell laminæ vary in depth according to the degree of amentia and dementia, and this variation takes place according to the order of normal development, L.V, the first to appear, being the least affected, and L.II, the last to appear, being the most affected. In amentia, therefore, the condition is one of true sub-evolution, and in dementia one of true dissolution or involution. In the case of Nos. 28 to 30, the decreased depth shown in L.II, and to some extent in L.III, is not indicative of the actual amount of neuronic loss, owing to the existence in these cases of more or less extensive reparative proliferation of the non-neuronic elements of the cortex.

Of these two layers of granules in the visuo-sensory area, both in the series of cases reach the normal depth in only one instance, and the lower layer is throughout much better evolved than the upper. In the visuo-psychic area, the granule lamina reaches up to or above the normal depth in nine of the twelve cases. On the other hand, in the prefrontal region, it is uniformly below the depth of the highest of the three normals in all the cases, and well exhibits a gradation according to the degree of amentia and dementia. Being the lamina, which is exceptionally evolved in the projection zones of the mammalian cortex, and being thus the layer which is especially concerned with the immediate transformation of afferent impressions, it is interesting to note the great variation in the degree of evolution of this lamina in the visuo-sensory region of the series of cases, and also that this variation is greater in the outer layer than the inner. I would further point out its relatively normal evolution in the visuo-psychic series, and its subnormal depth in the prefrontal series.

It is, I think, easy to arrive at a reasonable explanation of these differences in degree of development.

As I have already pointed out, the cortex of the visuo-sensory area is evolved earlier than that of the visuo-psychic, and this earlier than that of the prefrontal. It is therefore probable that in the case of the visuo-sensory area, the individual differences in the middle cell- or receptive lamina are indicative of individual differences in the functional capability of this lamina in different persons. On the other hand, in the prefrontal region the corresponding differences in the middle cell-lamina are simply greater in degree than are those in the inner cell-lamina, and less than are those in the outer cell-lamina, and are therefore due to the fact that the cortex of this region is as a whole in a condition of sub-evolution or dissolution according to the grade of amentia or dementia.

In other words, the granule-lamina of the visuo-sensory cortex exhibits considerable individual differences in its degree of evolution in different persons; the granule-lamina of the visuo-psychic cortex does not, being usually developed up to or above the particular normal with which they are compared; and the granule-lamina of the prefrontal cortex exhibits degrees of sub-evolution and dissolution which are part of the sub-evolution or dissolution of the whole cortex which occurs in this region alone, and varies in degree according to the existing grade of amentia or dementia.

I will now deal with the second lamina or pyramidal layer. This lamina passes the normal in one case in the visuo-sensory region, and in one of the three normal cases in the prefrontal region. In no other case does it reach the normal depth. In the visuo-sensory region it is in some cases better, and in others worse, evolved than in the visuo-psychic region. These differences bear no constant relationship to the degree of amentia or dementia. On the other hand, in the prefrontal region, the depth of this lamina varies directly according to the degree of amentia or dementia present. In normal evolution this lamina is the last of the cortical laminæ to be evolved, and it develops in the visuo-sensory area earlier than in the visuo-psychic, and in the visuo-psychic earlier than in the prefrontal region. It is poorly evolved in the lower mammalia, but rises in its degree of development during the ascent of the mammalian scale, as has been shown by G. A. Watson [25] and by Brodmann [9]. It is therefore concerned with the psychic or associational, in contradistinction to the instinctive, activities of the cortex. From the table of measurements it may be concluded that these are in man pre-eminent and voluntary in the prefrontal region, that they are of less general but of more specialized significance in the visuo-psychic region, and that they are of much less but nevertheless very specialized significance in the visuo-sensory area, in which the second lamina is normally but five-ninths of its depth elsewhere. Further, the individual variations in depth in the visuo-sensory and visuo-psychic regions of the series of cases point to real individual differences in the specialized functional capabilities of these regions, whereas in the prefrontal region the differences are not of an individual nature, but vary according to the degree of amentia or dementia which existed.

To turn finally to the general consideration of the cortex of each of these regions, I would again remind you that in normal evolution the visuo-sensory cortex develops before the visuo-psychic, and the visuo-psychic before the prefrontal, and also that the inner cell- lamina is evolved before the middle, and the middle before the outer. In view of these facts it is evident from the study of the different series of cases that the visuo-sensory cortex is rather better evolved and much more specialized and individually variable than the visuo-psychic; that the visuo-psychic is better evolved than the prefrontal, and that it also exhibits well-marked indications of specialization, and especially of individual variation; and that the prefrontal cortex shows clear indications, not of specialization and individual variation, but of sub-evolution or dissolution according to the grade of amentia or dementia. I would also indicate that, as the three normal cases show, the degree of its evolution varies considerably in normal individuals.

In the case of the visuo-sensory area, the specialization is indicated by the great depth and complexity of the third or granule-lamina, by the much decreased normal depth of the second or pyramidal lamina, and by the somewhat decreased normal depth of the fifth or polymorphic lamina, whilst the individual variation is chiefly visible, though not necessarily in the same direction or to similar degrees, in the outer granule-layer and the second or pyramidal lamina.

In the case of the visuo-psychic region, the specialization is indicated by facts of normal evolution which I have already pointed out, and by the well-developed third or granule-lamina; and the individual variation is especially evident in the second or pyramidal lamina.

In the case of both regions it may be added that, specialization being allowed for, whether the cases are considered individually or collectively, the degrees of evolution of the laminæ follow the normal order, the inner cell-lamina being better developed than the outer or middle.

In the case of the prefrontal region, whether the cases be considered individually or collectively, there is direct evidence of degrees of sub-evolution according to the grade of amentia, and of degrees of dissolution according to the grade of dementia. Further, this sub-evolution or dissolution involves the whole cortex, and this according to order of normal development, the inner cell-lamina exhibiting the least decrease and the outer the most.

Lest this should be doubted by any statistician, on the ground that the layers are not of the same depth and that, therefore, exact comparison is not possible, I have, in fig. 59, averaged together the depths of the laminæ of the various types of case, and turned these depths into percentages so that each lamina appears of the same depth. It will be seen that the inner cell-lamina is the first to be evolved and the outer cell-lamina the last; that the same order of sub-evolution applies according to the grade of amentia which existed; and that, in the case of dementia—also according to its grade—the outer cell-lamina, which is the last to be evolved, is the first to undergo dissolution, and the inner cell-lamina, which is the first to be evolved, is the last to undergo dissolution.

I will now complete this part of my subject by describing a special case in which I have exhaustively examined all the three regions under consideration. As far as it is possible to judge, the patient, before his illness, possessed at least the average normal degree of intelligence, and probably more. In the course of less than two years he gradually developed a well-marked grade of dementia, which was unusually profound

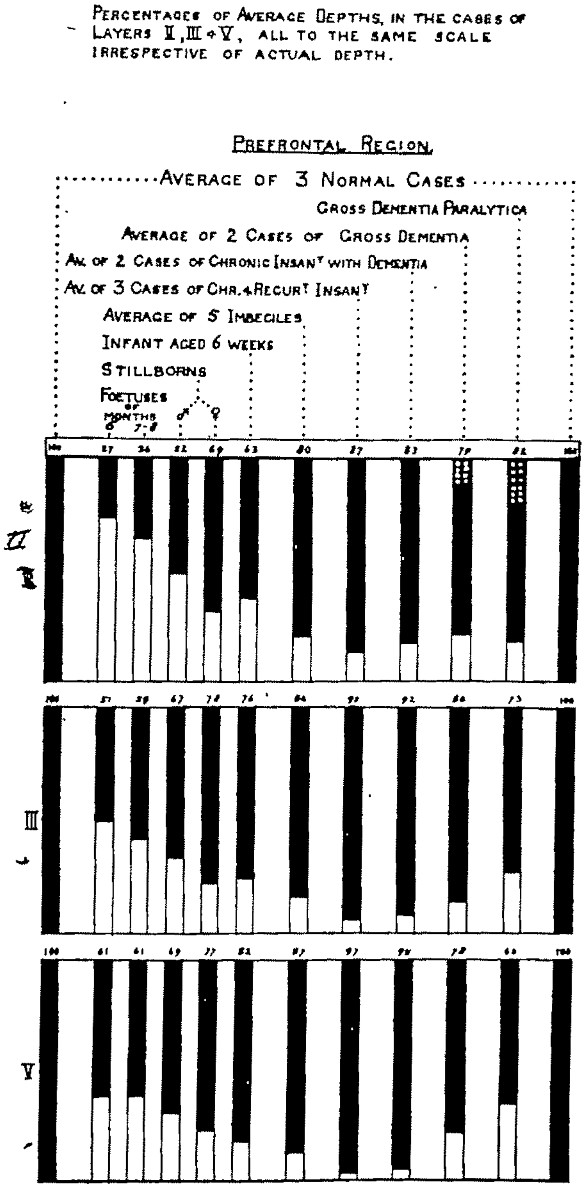


FIG. 59.

In this figure, for the purpose of direct comparison, the three cell-layers, of the prefrontal cortex of the cases which have been dealt with, are averaged into percentages of the normal, irrespective of actual depth. The figure proves that the inner cell-lamina develops before the middle, and the middle before the outer; that the same order of sub-evolution occurs in amentia; and that in dementia, if non-neuronic reparative proliferation in laminæ II and III be allowed for in the gross cases, the last lamina to develop is the first to undergo dissolution, and the first the last.

for a man of 44 years of age, who did not suffer from degeneration of the cerebral arteries. The cerebral dissolution was therefore of an unusually pure neuronic type; and it seemed to me, in view of the originally good development of the brain, that a better case could not well be found for the exhibition of the different grades of cerebral dissolution which might be expected to be found on examination of the visuo-sensory, visuo-psychic, and prefrontal regions of the cortex, since it was probable that all these, in their original condition, were of at least the average normal depth.

The results justified my expectation in that they showed quite clearly that the order of dissolution is the converse of that of normal evolution, the loss being most marked in the prefrontal region, next marked in the visuo-psychic zone, and least marked in the visuo-sensory area.

The results of the examination of this case are shown in the following diagram (fig. 60), in which are contrasted, in percentages of the normal, the general average measurements of the visuo-sensory, visuo-psychic, and prefrontal regions.

From the aspect of total depth, the visuo-sensory cortex is normal, the visuo-psychic shows a decrease of 6 per cent., and the prefrontal one of 13 per cent.

When the laminæ are individually considered there is, in the case of the outer cell-lamina or pyramidal layer, a 6-per-cent. decrease in depth in the visuo-sensory area, a 13-per-cent. decrease in depth in the visuo-psychic region, and a 24-per-cent. decrease in depth in the prefrontal region.

The middle cell- or granule-lamina is much below the normal in the visuo-sensory area, it is well above the normal in the visuo-psychic zone, and it is of practically the normal depth in the prefrontal region.

The inner cell- or polymorphic lamina is considerably above the normal depth in the visuo-sensory area, and is well above it in the visuo-psychic and prefrontal regions.

Whilst it is impossible to be certain as to whether the cortex was originally fully evolved or not, it is obvious that the visuo-sensory area possesses an individually deficient granule- or receptive lamina, and had commenced evolution in a manner which should have carried it beyond the level of the normal case. The latter remark applies equally to the visuo-psychic and prefrontal regions.

If, however, the cortex of this case be credited merely with evolution up to the level of the normal case, the significant fact appears that the pyramidal or psychic lamina has become decreased in depth by 24 per cent. in the prefrontal region, by 13 per cent. in the visuo-psychic zone, and by 6 per cent. in the visuo-sensory area.

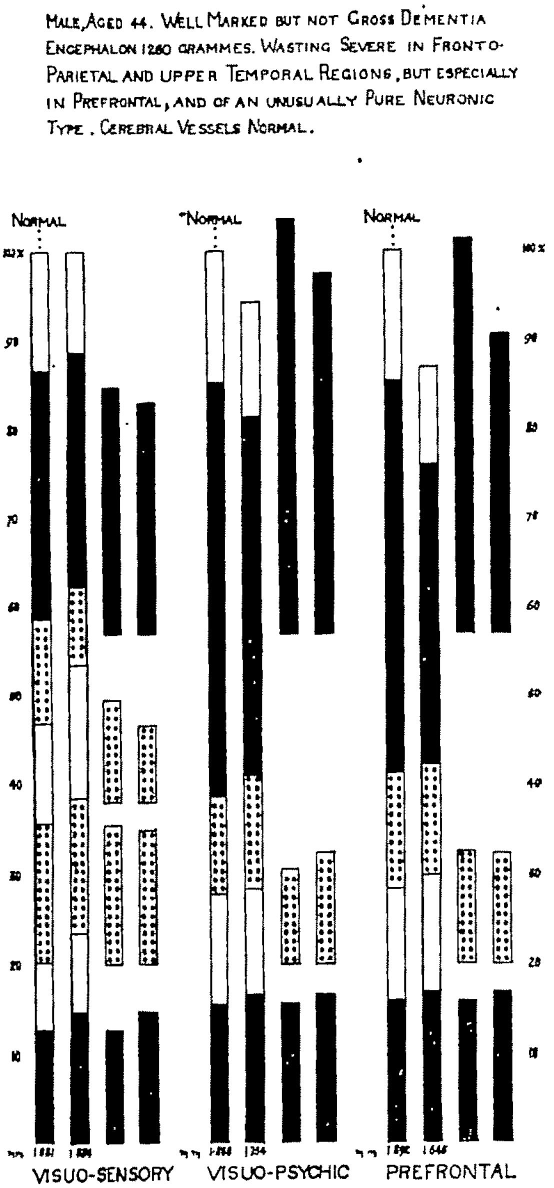


FIG. 60.

The figure shows, in comparison with the normal, the cortex of the visuo-sensory, the visuo-psychic, and the prefrontal regions of a case of well-marked dementia. From the aspect of total depth, the visuo-sensory area is normal, the visuo-psychic region shows a decrease of 6 per cent., and the prefrontal one of 18 per cent. In other words, the prefrontal region, which is the last to develop, shows the most affection, and the visuo-sensory area, which is the first to develop, shows the least. If the outer cell-lamina or pyramidal layer be considered alone, there is a decrease of 6 per cent. in the visuo-sensory area, one of 18 per cent. in the visuo-psychic zone, and one of 24 per cent. in the prefrontal region. The middle cell-lamina or granule-layer exhibits an individual decrease in the visuo-sensory area, and is very well developed in the visuo-psychic zone, and well developed in the prefrontal region. The inner cell-lamina is of a greater depth than that of the "normal" case in all the three regions, which fact suggests that the case under consideration was at any rate capable of development to a degree above that of this particular normal, even if this had not actually occurred.

Summary.—As a summary of the results of my micrometric studies, I would remark that the human cerebral cortex is originally evolved from three primary cell-laminæ; an inner or polymorphic, which is concerned with the performance of organic and non-voluntary activities; a middle or granule, which is receptive in function; and an outer or pyramidal, which serves as the physical basis of the associative or psychic functions of the cerebrum. The last of these, as has been shown by the investigations of John Turner [21] and of G. A. Watson [25], is the distinctive feature of the cortex peculiar to the mammalia, or the neopallium, to employ the term introduced by Elliot Smith.

These three laminæ appear during normal development, in the order in which I have stated them—namely, from within outwards—and the cortex of the visuo-sensory area is evolved before that of the visuo-psychic zone, and this before that of the prefrontal region.

In cases of mental disease grading from idiots and imbeciles through various types of non-demented and partially demented lunatics to the gross dement, great differences in the degree of evolution and dissolution of the cortex exist; and these, considered from the general aspect, follow the order of normal development. In amentia the condition is one of sub-evolution to different degrees, and in dementia the laminæ suffer in the reverse order to that of their evolution, the most affected being the latest developed, and the least affected being the earliest developed.

The degree and type of these differences vary according to the region of the cortex, whether this be a projection area, a zone of special association, or the prefrontal (higher associative) region.

In the case of the visuo-sensory area, the prominent features are poor evolution of the pyramidal and polymorphic laminæ and specialization of the granule or receptive lamina. There also exist individual variations in the degree of evolution of the granule or receptive lamina, and in that of the pyramidal or associative lamina, which individual variations bear no relationship to the degrees of amentia or dementia which exist in individual cases.

In the case of the visuo-psychic zone, the important feature, apart from an especially good evolution of the granule or receptive lamina, is a marked degree of individual variation with regard to the depth of the pyramidal or associative lamina. This individual variation is independent not only of the existing grade of amentia or dementia, but also of the individual variation in this lamina which occurs in the visuo-sensory area.

In the case of the prefrontal region, both specialization and individual variation are practically or entirely absent, and the cortex merely exhibits degrees of sub-evolution or dissolution which vary according to the grade of amentia or dementia which exists in the individual cases. That the condition is one of true sub-evolution is shown by the fact that the laminæ are sub-evolved in the order of their normal development, the last to appear being the least developed, and the first the most. The reverse order holds with regard to dissolution, the last lamina to appear during normal development being the first to undergo retrogression in dementia, and the first the last. In the case of the cortex of the prefrontal region, therefore, the associative function of the pyramidal lamina may be regarded as "*voluntary* associative," in view of the fact that the essential feature of amentia and dementia is decrease, instability, or loss of voluntary control over the processes of cerebral association.

As a final remark, I would add that there is reason to believe that this physical basis of the cerebral functions, which exhibits such well-marked variations in the subjects of mental alienation, exhibits equally important though less extensive variations in the case of presumably normal individuals; and thus indicates a structural origin for individual differences in mental endowment.

CHAPTER VII.

The Pre-Rolandic or Psychomotor Cortex.

Having completed the description of my observations and deductions with regard to the structure and functions of the visuo-sensory (or sample sensory projection), the visuo-psychic (or sample special associative), and the prefrontal (or higher voluntary associative) regions of the cortex, I now pass on to certain observations with regard to the structure and functions of the final type of cortex with which I propose to deal—namely, the pre-Rolandic or psychomotor.[1]

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[1] The last number of BRAIN contains a paper by H. Charlton Bastian on "The Functions of the Kinæsthetic Area of the Brain." Bastian repeats his view that "the so-called 'motor-centres' are in reality sensory centres for the registration of a complex set of impressions (kinæsthetic) occasioned by movements" (p. 327); and he remarks that "it will soon be more widely recognized that there is not the slightest need for postulating the existence of 'motor' or of 'sensori-motor' centres in the cerebral cortex" (p. 340). He speaks of "a very indefinite, and to me meaningless, view suggested by some who speak of this region as containing 'psychomotor' centres. This metaphysical suggestion is neither helpful nor in any sense explanatory. It will be better, therefore, to cease to use a nomenclature which is not in harmony either with modern psychological or physiological science" (pp. 327-28).

I trust that the evidence I have produced in these lectures with regard to the structure

It is unnecessary for my purpose to describe in detail the great controversy which raged for so many years as to whether this region possessed purely motor or sensori-motor functions. I shall merely remind you of how the histological researches of Bevan Lewis and Henry Clarke, which as long ago as 1878 resulted in the delineation of the Betz-cell area, were forgotten in the heat of the controversy until 1901, when, through the experimental work of Sherrington and Grünbaum, followed by the histological researches of Campbell and of Brodmann, they finally received belated recognition.

Since that time the majority of observers have credited the precentral gyrus with motor, and the postcentral with sensory, functions; and this opinion received confirmation, so far, at any rate, as the experimental method can be regarded as capable of affording it, from the researches of Oskar Vogt [23], who in 1906 published a paper describing the results of stimulation and extirpation of the precentral and postcentral gyri. In brief, Vogt concluded that palsy without ataxy followed destruction of the precentral gyrus, and that ataxy, but no palsy, resulted from destruction of the postcentral gyrus. Last year, however, in the Linacre Lecture, Victor Horsley [15] described what he regards as a crucial test case, and reiterated his conviction that the so-called motor area is really sensori-motor. From this patient, who suffered from athetoid movements of the left hand, followed by violent convulsive movements of the whole upper limb, Horsley removed by operation the portion of pre-Rolandic cortex which, as the result of stimulation, he concluded to constitute the whole of the arm area. He carefully describes the immediate results which were partly motor and partly sensory, and the remote results (a year later), which consisted of permanent absence of spasmodic movements, partial recovery of voluntary movement of the left upper limb, and considerable recovery from the sensory disability. On this case Horsley bases his contention that the precentral gyrus is sensori-motor in function.

The evidence which I purpose laying before you points to very different conclusions regarding the functions of this region of the cortex, and, unless these conclusions are correct, the whole of my

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and functions of the "psychomotor" area will be sufficient to absolve me from the reproach contained in the last quotation.

I am responsible for coining the terms "visuo-sensory" and visuo-psychic," which latter seems to me preferable to "visual cerebral-associative"; and these terms have been generally adopted and have been extended by Campbell and others to the auditory, &c., areas. The term "psychomotor," employed by me in preference to the cumbrous "cerebral-associative motor," seems equally satisfactory. I hope to be pardoned for failing to see in it any "metaphysical suggestion."

previous observations and deductions fall to the ground. I would therefore submit that in my opinion the experimental method, even in the hands of so renowned an operator as Horsley, cannot be regarded as trustworthy. On purely theoretical grounds, it might well be doubted whether a gyrus of considerable size could be removed without any disturbance of the functions of the immediately adjacent gyrus resulting, but in this instance anatomical reasons exist which appear to me to render such an operation a practical impossibility. To indicate these I will now show (fig. 61) naked-eye sections through the fissure of Rolando, which are situated above and below the buttress and thus indicate the arrangement of the neighbouring gyri in both these positions. I introduce the two sections in order to avoid the possible criticism that the arm area is not included, since this area was placed above the buttress as the result of the earlier stimulation experiments on man, although it is now considered to lie below this annectant.

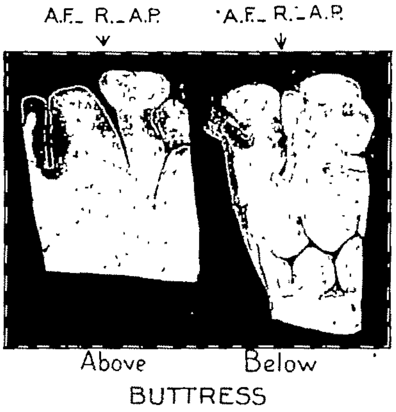

Fig. 61.

Naked-eye sections across the central convolutions. The left-hand section is above the buttress, and the right-hand section is below this annectant. R., furrow of Rolando; A.F., precentral or ascending frontal gyrus; A.P., postcentral or ascending parietal gyrus. Both sections show the extremely narrow neck of the postcentral gyrus, and the right-hand one also indicates the proximity of the gyri of the parietal operculum. The figure demonstrates that removal by operation of the precentral gyrus, however skilfully performed, must necessarily result in functional, and probably also in structural, damage to the fibres entering the neck of the postcentral gyrus.

In the first section, which is above the buttress, is seen the extremely narrow neck of the gyrus postcentralis, and the nearness of this to the site of operation.

In the next section, which is below the buttress, the same point is equally clearly visible, as is also the relative nearness of the gyri of the parietal operculum to the seat of operation.

Apart entirely from the intimate structural and functional associations of the pre- and postcentral gyri, these photographs in my opinion indicate the probability, I may even say the certainty, that removal of the precentral gyrus, however carefully performed, will result in functional, if not also in actual structural, disability of the fibres passing to and from the postcentral gyrus.

I now pass on to the consideration of the structure of the precentral gyrus, from the aspect of cell lamination. In the case of this region I have not resorted to the micrometric method, partly because the structural conditions preclude the possibility of obtaining a series of measurements from the four situations I am accustomed to select, and partly because the practical absence of a middle cell-lamina or granule-layer renders measurement of this lamina untrustworthy even if possible. I therefore propose to illustrate my point, not by series of measurements from human subjects, but by exhibiting certain mammalian cortices which show the depths of the various laminæ in a cruder but equally satisfactory manner. As a preliminary remark I would state that the lamination of the precentral gyrus, though to the inexperienced eye indefinite, is of the usual general type, consisting of an *outer fibre-* or superficial *lamina*, an *outer cell-* or pyramidal *lamina*, a *middle cell-* or granule-*lamina*, an *inner fibre-lamina* or inner line of Baillarger, which here contains the Betz cells, and an *inner cell-* or polymorphic *lamina.*

The photographs which form the following figures are strictly comparable, apart from the somewhat lower magnification of fig. 64.

The following plate (fig. 62) is taken from the Betz- cell region of the dog. It shows all the five laminæ—namely, the superficial, the pyramidal, the indefinite granule, the inner line of Baillarger with Betz cells, and the polymorphic lamina.

I wish particularly to draw your attention to the fact that the second lamina or pyramidal layer (·45 mm.) is in depth about one-third of the combined depth of the laminæ below it (1·18 mm.) I would also point out the large size and generally embryonic condition of the cells in all the laminæ.

The next photograph (fig. 63) illustrates the precental cortex of the rhesus, with its five laminæ.

I would particularly ask you to note that the depth of the pyramidal lamina (·91 mm.) is practically equal to the conjoined depth of the laminæ below it (·90 mm.), and also that the individual cells of all the

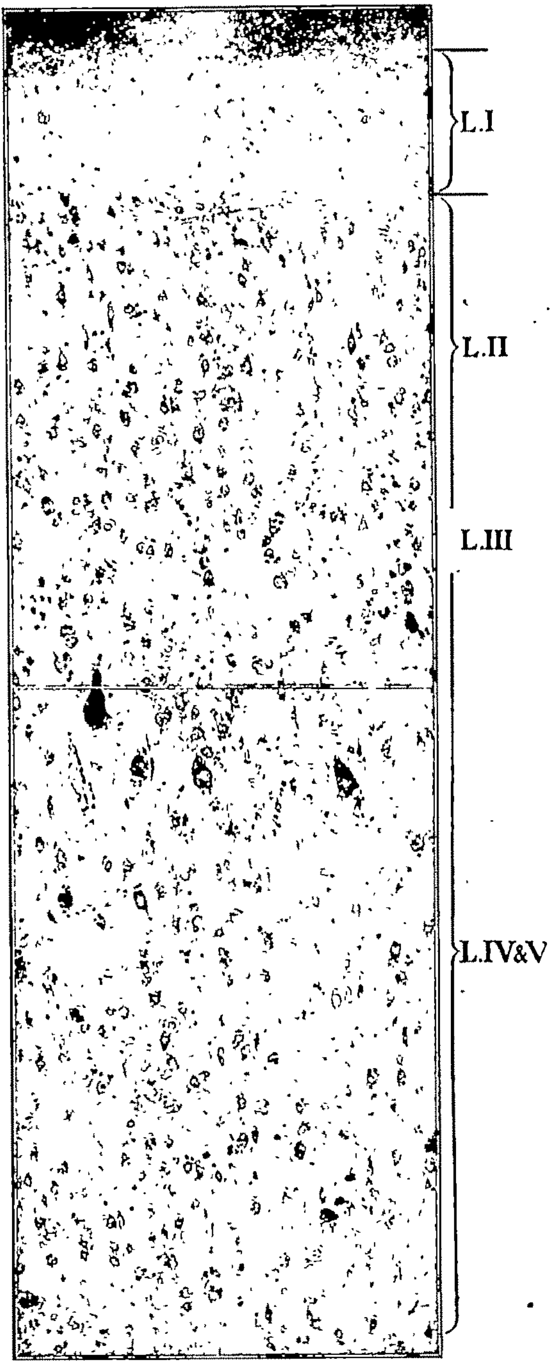

FIG. 62.

Eighty-nine diameters, Cortex of the Betz-cell area of the dog. L.I, outer fibre- or superficial lamina; L.II, outer cell- or pyramidal lamina; L.III, the indistinct middle cell- or granule-lamina; L.IV and V, the inner fibre-lamina, or inner line of Baillarger containing Betz cells, and the inner cell- or polymorphic lamina. The depth of L II is about one-third of the conjoined depths of L.III to L.V. The cells are of large size, and are embryonic in appearance.

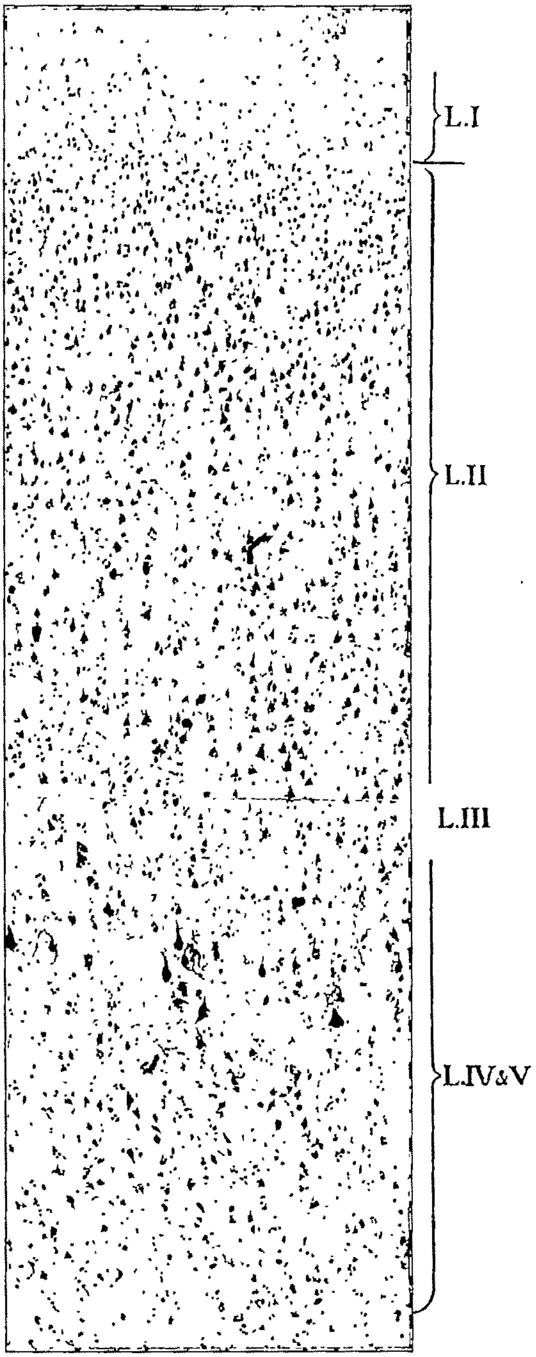

FIG. 63.

Eighty-nine diameters. Cortex of the Betz-cell area of the rhesus. L.I to L.V as in the preceding figure. The depth of L.II is practically equal to the conjoined depths of L.III to L.V. The constituent cells are smaller and more numerous than in the dog, and are also better made and relatively further apart.

laminæ are smaller and more numerous than in the dog, and are also better made, and relatively more widely separated from one another.

The next photograph (fig. 64), less highly magnified, shows the cortex of the human precentral gyrus, with its five laminæ.

I would draw your attention to the fact that the second or pyramidal lamina (1·24 mm.) is in depth four-thirds of the conjoined depth of the laminæ below it (·92 mm.), and also to the detail that the individual cells are very well made, and are more widely separated from one another than in the rhesus.

A study of these cortices leads to the following conclusions:—

The outer cell-lamina or pyramidal layer of the dog is one-half of the depth of that of the rhesus, which again is three-fourths of that of the human subject.

The middle cell-lamina is so deficient in depth as to be practically invisible, except to the experienced observer.

The conjoined depth of the lower laminæ is practically the same in the rhesus and man, and is one-fourth deeper in the dog than in the others.

The ratio of the depth of the second or pyramidal lamina to that of the three lower laminæ is in the dog about one-third, in the rhesus 1/1, and in man 4/3. In man, therefore, the precentral ratio is as high as or slightly higher than in the prefrontal region, in which general average measurements give an average ratio of about 11/10.

As a very rough analogy, the pyramidal lamina of the dog may be compared with that of a stillborn infant; and the pyramidal lamina of the rhesus with that of an imbecile.

Finally, in passing from the dog to the rhesus, and from the rhesus to man, there is a very marked and progressive improvement in the development of the individual cells in all the laminæ, which general improvement, however, pales before the great difference which exists in the three cortices with regard to the evolution, both in depth and in content, of the outer cell- or pyramidal lamina.

In view of the conclusions which I expressed in the last chapter with regard to the functions of the primary cell-laminæ of the cortex, the deduction is evident.

The outer cell- or pyramidal lamina, which is of psychic, associative, and educative significance, is the prominent feature of the precentral cortex of man.

The granule- or receptive lamina is reduced to a minimum depth in

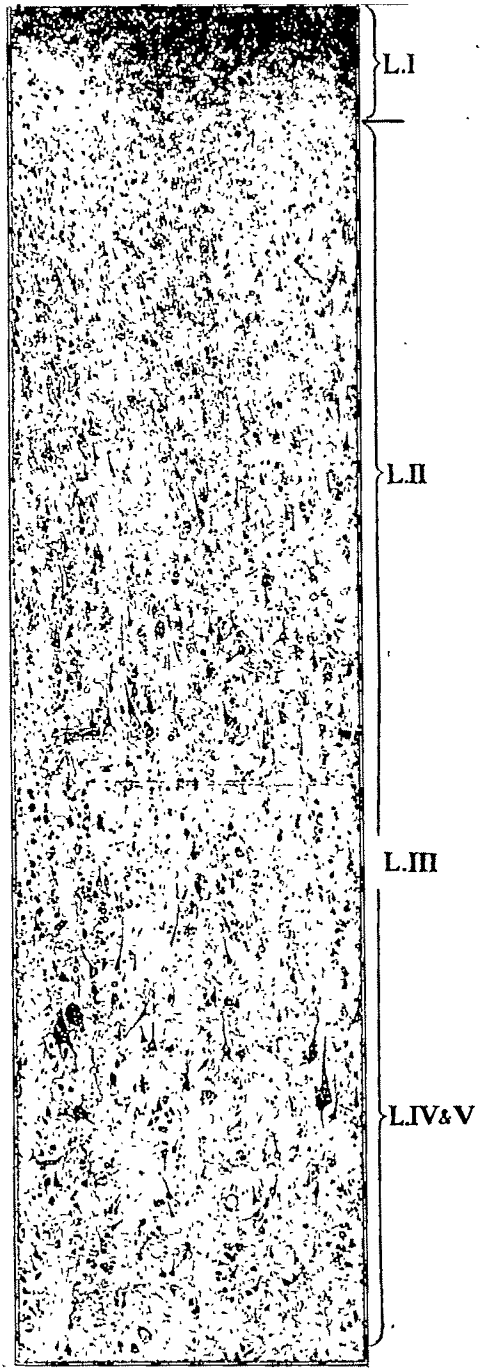

Fig. 64.

Seventy-four diameters. Cortex of the Betz-cell area of man. The magnification is five-sixths of that of figs. 62 and 63. L.I to L.V, as in the preceding figures; L.II in depth $\frac{1}{3}$ of the conjoined depths of L.III to L.V. The constituent cells are very well made, and are further apart than in the rhesus. A comparison of figs. 62 to 64 shows that the essential differences between the cortices consist in a very marked and progressive improvement in the development of the individual cells in all the laminæ, and, particularly, in the degree of evolution of L.II, the pyramidal lamina, of the several cases. L.II, the outer cell- or pyramidal lamina, which is of psychic, associative, and educative significance, is thus the prominent feature of the precentral cortex of man. L.III, the granule- or receptive lamina, is reduced to a minimal depth in all the cortices. L.IV and L.V, which are of organic and instinctive significance, are similar in type in man and the rhesus, and in the dog their depth is somewhat greater, and their constituent cells are more embryonic in structure.

all the cortices. This fact negatives the possibility of the existence of sensory-receptive functions in this part of the cortex.

The fourth and fifth laminæ, which are of organic and instinctive significance, are of the same depth and general type in man and in the rhesus, and in the dog their conjoined depth is one-fourth greater and their individual cells are more embryonic in structure.

The obvious conclusion, therefore, is that in man the psychic, associative, and educative functions of the precentral gyrus are paramount; that in all three the receptive functions are minimal or non-existent; and that the organic and instinctive activities are approximately on the same level in all the three.

When this conclusion is regarded in association with the well-known truth that the particular type of cortex under consideration increases in area and differentiation during the ascent of the mammalian scale, not according to muscular bulk but according to the degree of motor educability exhibited by the several parts of the body, the further conclusion that the Betz cells merely serve as a relatively simple motor mechanism, and that motor educability must have its seat in the second or pyramidal lamina, is inevitable. That the Betz cells serve as the origin of the pyramidal tracts has long been believed. It is, in fact, many years now since I noticed well-developed Betz cells in the cortex of a fœtus of six months, and therefore took for granted that they served as the origin of these tracts. The truth of this presumption has recently been finally proved by Holmes and Page-May [14]. Further, it has long been known to physiologists that whilst the pyramidal tracts normally conduct voluntary efferent impulses, such impulses in the functional absence of these tracts can still find passage. For example, a hemisection of the spinal cord of a dog, followed by a higher hemisection on the opposite side, and this again followed by a still higher hemisection — this time on the original side — results in at least a very considerable return of power over both lower limbs.

It may thus be regarded as proved that the Betz cells serve not as the psychomotor cortical mechanism, but simply as a subservient mechanism for the direct transmission of voluntary impulses to the lower motor centres.

I may add, as a necessary consequence to this conclusion, that the Betz-cell distribution need no longer, therefore, be regarded as indicative of the limits of the cortical zone concerned with the evolution of those associational processes which, when translated by the agency of the lower motor centres into muscular movements, constitute the sole objective indications of cerebral activity. If, as I consider proved, reliance can be placed on the results of the histological investigations of the past decade, the educable psychomotor cortex, with little modification, extends over almost or quite the posterior half of the frontal lobe, where it grades, through cortex of an intermediate type, into that of the prefrontal region.

Having, as I hope, sufficiently indicated my reasons for regarding the precentral cortical zone as psychomotor, rather than motor or sensori-motor, in function, I will now exhibit as a histological contrast a plate prepared from an illustration (fig. 65) published by Gordon Holmes [13], in order to show the well-defined middle cell-lamina or granule-layer which exists in the postcentral gyrus. The proportion which the depth of this lamina bears to the total depth of the cortex—namely, about one-eighth—is, to me at any rate, sufficient almost to prove that this cortex belongs to a sensory-projection sphere; in other words, to indicate with great probability the performance of sensory-receptive functions by the postcentral gyrus.

CHAPTER VIII.

Provisional Scheme of the Localization of Cerebral Function.

The general trend of the results of the recent histological survey of the cerebral cortex, which followed the enunciation by Flechsig of his doctrine of centres of projection and centres of association, and which has culminated in the elaborately detailed descriptions of Brodmann, has, to say the least, been highly suggestive of the existence of a definite correlation between histological structure and functional significance; and it is probable that the histological method, without entirely replacing the experimental, will in the future be still more fruitful in this direction. In the personal investigations which I have described I have endeavoured by the employment of subnormal and pathological material to obtain proof of the functional significance of certain of the histologically differentiated regions of the cortex. Such proof as I have obtained leads me to adopt, as a partially proved provisional hypothesis, the following scheme of the localization of cerebral function. I do not claim originality, except with regard to the production of proof of functional significance, since in dealing with cerebral function one needs to select rather than to enunciate opinions, owing to their multitude.

I would regard the human cerebrum, not as a sensori-motor, but as an intermediate or associative ganglion, which, on the one hand, receives

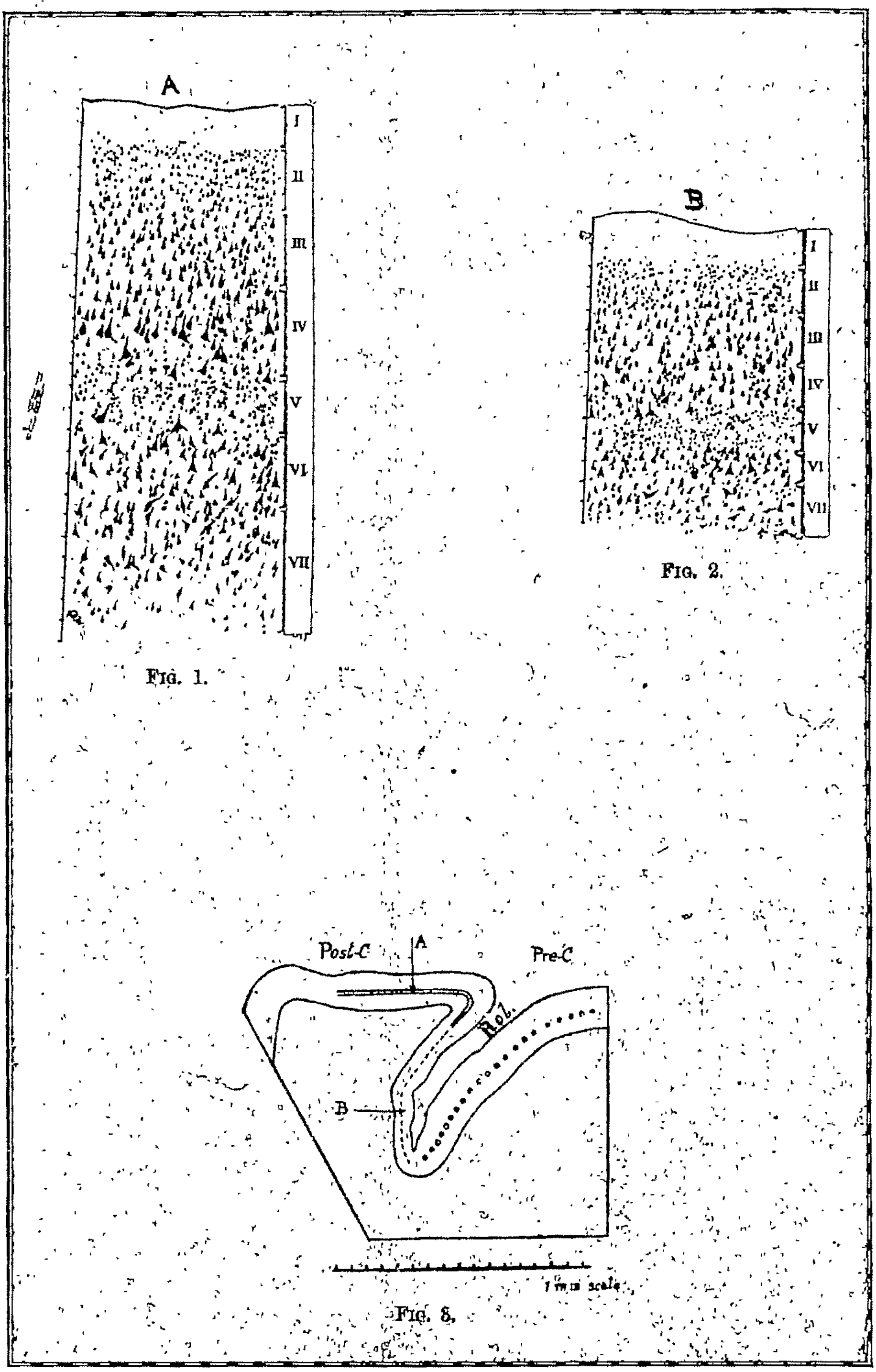

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 65.

(Gordon Holmes.) In A and B respectively is shown the structure of the cortex of the postcentral gyrus at the regions indicated in the lower diagram. I = L.I, the outer fibre- or superficial lamina; II to IV = L.II, the outer cell- or pyramidal lamina; V = L.III, the middle cell- or granule-lamina. VI and VII indicate respectively L.IV, the inner fibre-lamina, and L.V, the inner cell- or polymorphic lamina. The possession of such a well-developed granule-lamina (V = L.III) by the postcentral gyrus markedly contrasts with the almost complete absence of this lamina in the precentral gyrus. The performance of sensory-receptive functions by the former gyrus is therefore highly probable.

sensorial impressions and elaborates them, by processes of association, into the physical equivalents of psychic products of high complexity, and which, on the other hand, to a variable extent controls, selects, and co-ordinates certain of these equivalents, eventually transforming them into further physical complexes, whose function is to set in action the lower motor centres. On this functional basis I would divide the cerebrum into pre- and post-Rolandic portions, the former of which possesses controlling and executive functions, and the latter receptive and elaboratory.

I would subdivide the pre-Rolandic part, or frontal lobe, into a posterior or psychomotor area which is concerned with the evolution of such physical complexes as are necessary to give external expression to the results of cerebral association; and into an anterior or prefrontal area which is able to control, select and co-ordinate certain of the results of post-Rolandic cerebral association, and either to allow these to undergo psychomotor transformation or to inhibit this process. Both these functions I regard as proved, and I consider the outer cell or pyramidal lamina of the cortex to be at least the chief seat of their actual performance.

The cortex of the post-Rolandic portion of the cerebrum I would regard as consisting of projection areas, of which the visuo-sensory area is a type. Each of these is surrounded by, or possesses in its proximity, zones of special association, of which the visuo-psychic region is an example, which zones are hall-marked in function according to their appropriate projection areas. It also consists of intermediate cortex, in which are fused and elaborated the results of the special processes of association. I consider the functions of the visuo-sensory and visuo-psychic regions of the cortex to be proved, and, from homology, the functions of the other areas of projection and special association, the exact location of which is still probable rather than certain. I regard the outer cell- or pyramidal lamina as at least the chief physical basis of these processes of association, and the middle cell- or granule-lamina of the projection areas as the region concerned with the reception and immediate transformation of sensorial impressions. I may, perhaps, here remind you that the middle cell- or granule-lamina attains to its maximum degree of development in the sensory-projection areas, and that it continues to be well developed in the special zones of association. In both these types of cortex there is no clear line of demarcation from the laminæ above and below it. The granule-lamina is of good development in the posterior region of general association, and also in the prefrontal area, in which latter it is more distinctly separated from the laminæ above and below it than in any region with which I am familiar. From the prefrontal region backwards, the granule-lamina decreases in depth and distinctness until, in the psychomotor area, it reaches a minimal depth and is barely discernible.

The inner cell- or polymorphic lamina, as I have already stated, has been shown to be the prominent lamina in the lower mammalia, and must be regarded as subserving such organic and instinctive activities as are not acquired by education. It is probable, for reasons which I have indicated, that this is its function in man.

CHAPTER IX.

The Nature of Language and the Language Mechanism.

For the further consideration of this scheme of cerebral function, and, in particular, in order to indicate the probable nature of the cerebral processes which subserve the exhibition of certain of the more important symptoms of mental disease which do not fall under the gross generalization of amentia and dementia, it is necessary that I should now introduce a few observations with regard to the nature of language.

Owing to the complexity of even the more elementary processes of cerebral association, a mechanism for the symbolic representation of the results of these processes soon becomes a necessity. The mathematician, for example, has evolved a complex system of symbols in order that he may be able to perform complicated operations with masses of figures elaborated from the ten numerals alone. He thus unconsciously imitates the infinitely more complex system which has been elaborated in association with the higher evolution of the cerebral functions—namely, the language mechanism—whose " numerals," or sensori-memorial images and crude sensations, are innumerable.

Words, or language symbols, are of very different representative value. Articles, pronouns, prepositions, conjunctions, interjections, and the simpler adjectives, adverbs, and verbs, when thought of alone, as a rule arouse little beyond their respective visual or auditory word-images, which in themselves are meaningless.

Adjectives, adverbs, verbs, and abstract nouns, when thought of alone, arouse first their respective visual or auditory word-images. These, however, are meaningless until by complex processes of association they are defined and illustrated through the sensori-memorial spheres attached to the various sensory or projection areas.

Common or proper nouns, when thought of alone, may first arouse their visual or auditory word-images; but they frequently at once awaken a whole series of processes of association, and thereby determine the reproduction of sensori-memorial images attached to one or more of the several sensory or projection areas. I may remark that each of such series of processes of association differs in detail on each occasion on which it is evolved. For example, the mental processes induced by the word " microscope " are different, not fundamentally but in detail on each occasion on which they are aroused. This ever-varying perceptive content is consequent on the revivification of, and the modification of the complex relations of, the numerous existing sensori-memorial images of which the word is symbolic, which are constantly taking place under the influence of even apparently unrelated afferent impressions.

Perception, therefore, is a cerebral process which is similar in nature, but differs in detail, on each occasion on which it occurs. It is thus incorrect to speak of a cerebral centre for percepts, which are psychic products that, except by accident, need never be identical even if the arousing sensation is the same. I may remark that perception can hardly be described as the act of naming objects, for it is as often the reverse—namely, the act of applying one or more sensori-memorial images to a name, or the identifying of a sensation with a sensori-memorial image. The last corresponds to the crude perceptions of animals; the others to perceptions involving the employment of the symbolic mechanism of language.

Similarly, the process of conception may take the form either of generalization from a series of sensori-memorial images to a general name, or of revivification of a series of sensori-memorial images in order that the meaning of a general name may be interpreted. This process is invariably a very complex one, and necessarily differs in detail, in spite of a general similarity in nature, on each occasion on which it occurs. It is thus incorrect to speak of a cerebral centre for concepts.

Language is produced by the suitable co-ordination of words of different symbolic value; and by its means alone is it possible to perform the highly intricate processes of cerebral association which form the physical bases of judgment and reasoning.

Words are, from the afferent aspect, mere sensations, the memories of which are stored in the appropriate zones of association attached to the particular cortical projection areas to which they happen to pass. For example, a word seen stimulates the visuo-sensory area, and the resulting image is stored in the neighbouring visuo-psychic region.

On the other hand, from the efferent aspect, words are mere articulatory or cheiro-graphic results of the action of complex neurone groupings in the outer cell- or pyramidal lamina of the psychomotor area. This fact may be illustrated by the common observation that children learning to write contort their faces and tongues during their endeavours to perform the necessary manual operations.

In the complete mechanism of language, words thus possess, from the afferent aspect, four sensori-memorial bases in the cortex—namely, in the neighbourhood of the auditory and visual projection areas of the cortex, and in that of the kinæsthetic projection area lying behind the fissure of Rolando, in especial relation to those portions concerned with the reception of sensations from the larynx and the hand.

From the efferent aspect, words possess two motor-memorial bases in the neighbourhood of those parts of the psychomotor area lying in front of the fissure of Rolando, which have been shown both experimentally and histologically to be concerned with the evolution of acquired movements of the larynx and the hand.

Words are originally acquired and reproduced through imitation by means of the auditory and articulatory word-centres, the latter working in conjunction with its sensory coadjutor, the articulatory-kinæsthetic word-centre.

In the evolution of the mechanism of language, suitable and highly complex associations occur between these various word-centres. These associations are of such a nature that the language machine can, and frequently does, act as a mere mechanism for the evolution and reproduction of language which to the individual may be meaningless.

For example, children when learning to speak are often obviously ignorant of the meaning of the phrases they employ; and when older learn a large portion of their lessons by rote and frequently but feebly appreciate their meaning. Adults can learn the Lord's Prayer backwards, or sentences in an unknown foreign tongue; and uneducated persons are often fond of using, and quite wrongly using, words which take their fancy and the real meaning of which they do not in the least understand. Imbeciles can sometimes learn by rote long paragraphs of the meaning of which they are ignorant. Lunatics often employ the language machine in an almost entirely mechanical manner.

Examples of this mode of employment of the language mechanism may be readily drawn from everyday life. Many word-complexes which are frequently repeated—e.g., daily prayers—are often gone through in a purely mechanical manner, whilst the individual reproducing them is, perhaps, thinking of something else. Again, it is appreciated by few that language, as normally employed, is very largely a purely reflex, or, at any rate, automatic function, and that the significance of what is spoken is but feebly appreciated by the speaker. This is particularly evident in the case of persons who talk without having anything particular to say, and who bore every listener they meet with the same personal experiences, the same stale stories, and the same gossip.

By these few remarks I have endeavoured to indicate and illustrate the fact that words are merely symbols which possess different grades of value, and which are meaningless unless they are employed to incite the occurrence of such processes of cerebral association as are necessary to awaken the various sensori-memorial images of which such words are but the symbols. In order, therefore, that language may possess meaning, there necessarily occurs, during the employment of its mechanism, an active associational participation on the part of practically the whole mantle of the cerebrum.

As a preliminary to the consideration of the manner in which the language mechanism is voluntarily employed, I would remark that words, in my opinion, invariably arise into consciousness through the activity of sensory spheres, and may do so through that of any one of them. When, however, they are voluntarily and silently reproduced—i.e., thought of—words are invariably awakened through the articulatory-motor word-centre under normal conditions. Further, this reproduction requires a muscular effort, and cannot take place without a definite attempt at articulation, usually, but not necessarily, accompanied by a slight expiration. Again, words cannot be voluntarily repeated in thought by means of the cheiro-graphic centre if the hand is not actually moved, unless such hand-movements are replaced by slight movements of the head, or even of the lower jaw or the eyes, through the agency of their respective motor spheres. Such observations as I have just indicated are valuable because they render it probable, if not certain, that the important factors in the reproduction are not the muscular movements but the sensory impulses derived from them; otherwise there is no reason why such muscular movements should not be imagined, without any attempt at their actual performance. I thus consider that words, when voluntarily reproduced, are invariably awakened through the preliminary action of the prefrontal region on the psychomotor area, activity of which results in stimulation of appropriate neurone complexes subserving the evocation of the particular sensori-memorial images, which arise in the zone of special association attached to one or more of the sensory projection spheres. This view, I may remark, is merely an elaboration of that long ago advanced by Hughlings Jackson, more recently supported by Stricker, and strongly combated by Bastian [1].

Whether the rousing of such sensori-memorial images is followed by further processes of cerebral association, and what these further processes are, if they occur, depends partly on the general condition, as regards excitability, of the lower centres of association and partly on such degree of voluntary guidance and control of these processes as happens to be exercised. For example, in dreamy states, when voluntary selection, co-ordination, and control are at a low ebb, processes of lower association, involving the awakening of all kinds of sensori-memorial images, occur in a more or less riotous manner according to certain general laws which are well known and need not be further referred to here. On the other hand, as an extreme example, during the voluntary employment of written or spoken language for the evolution and reproduction of the higher psychic products—e.g., the production of an abstruse thesis—voluntary control over, and guidance of, the processes of lower association is paramount. In such a case, however, there is a tendency, which requires to be continually combated, for the cerebral processes to keep to the general lines of the mechanism of language, to the exclusion of such processes as involve the evocation of visual sensori-memorial images of the ordinary type. In other words, during the voluntary employment of written or spoken language for the evolution and reproduction of abstract thought, there is a tendency for the performer to become unintelligible to others, and perhaps even to himself, unless he continually reverts to concrete examples.

CHAPTER X.

Defective Control of Processes of Lower Association in Mental Disease.

In the insane—as I shall now illustrate by examples—voluntary control over the processes of lower cerebral association, including the activity of the language mechanism, is to a greater or a lesser extent defective.

In amentia, according to its grade, such voluntary control is permanently or temporarily defective. In many of the lowest types the mammalian tendency to sleep, unless the processes of lower association are stimulated by sensory or organic stimuli, is observable. On the other hand, in attacks of simple mania occurring in the higher grades of amentia, the prefrontal centre of higher control is in functional abeyance and the cerebrum acts as an uncontrolled sensori-psychomotor machine. Instead of — as normally happens — but a small selected number of the ever-entering stream of afferent impressions being noticed, almost every visual and auditory stimulus which arrives at the cortex is accepted. Processes of cerebral association incited by these occur pell-mell, and find motor expression in emotional disturbance, rapid movements, and a riotous display of words. It is impossible to obtain more than the momentary attention of the sufferer. This condition of uncontrolled sensori-psychomotor activity may last for hours, days, or weeks, after which the patient becomes—at any rate for the time—sane.

Again, in dementia, according to its grade, voluntary control over the cerebral processes of lower association is permanently defective or absent. If this be defective, and the centres of lower association be normal, the chief clinical features exhibited by the patient are a general hebetude and a lack of interest in his surroundings. If, however, aberrant states of the centres of lower association exist, certain additional symptoms, to which I shall refer later, are presented. Further, in the grosser grades of simple dementia, no evidence whatever of the existence of cerebral activity may be exhibited or obtainable, and the patient is an inanimate object, unable even to feed himself or to attend to the calls of nature.

I will mention as a final example the numerous cases of premature dementia which exhibit strange motor phenomena, and which are commonly classed under the term "catatonia." I believe that these phenomena are due to the occurrence of a more or less extensive dissolution of the neurones of the psychomotor area in certain subjects, usually juvenile, in whom the fundamental psychomotor neurone-groupings are still imperfectly organized into relatively stable complexes. The pathological condition is thus, on the one hand, one of sub-evolution of function, and, on the other, one of dissolution or involution, the tract of cortex involved being practically the whole frontal lobe.

Such motor phenomena resemble, in brief, those which would occur in a "Frankenstein-man" or "mechanical model," in which certain parts were imperfectly fashioned; in which certain groupings of parts were imperfectly tested and not in proper running order; in which the higher mechanical complexes were imperfectly controlled and co-ordinated into series, and, therefore, tended to stop, to repeat action, or to go by fits and starts; and in which, owing largely to the existence of several sources of motive power (i.e., from the different organs of sensation), certain mechanical complexes tended to run independently in consequence of an imperfect general co-ordination of, and control over, the whole mechanism. The motor phenomena are thus varied, and are, on the whole, of a distinctly positive or a definitely negative nature; and repetition, wayward and grotesque action, &c., are common.

In chronic cases the phenomena are often still further complicated as regards an immediate explanation, but simplified as regards their actual exhibition, by a more or less extensive dissolution of neurones, which results in stereotyped motor remainders of former skilled accomplishments. These, occurring on the dissolution side of the scale, differ in character from the erratic, grotesque, repeated, mechanical-model-like, and often unskilled movements which occur on the sub-evolution side and are due to imperfect control and insufficient practice.

That this explanation is probably correct is indicated by the fact that in a series of chronic cases of premature dementia without motor phenomena, 55 per cent. exhibited a moderate grade of dementia, whereas in a series presenting motor phenomena as many as 73 per cent. had attained a moderate grade of dementia. I may remark that this grade of dementia indicates the existence of intracranial morbid appearances of moderate intensity, these representing the usual final stage which cerebral dissolution reaches in the absence of marked degeneration of the cerebral arteries.

Chapter XI.

Independent Activity of the Centres of Lower Association. Illusion and Hallucination.

I now pass to the consideration of certain phenomena due to the independent activity of the centres of lower association. Words, when voluntarily reproduced in thought, are awakened through the action of the prefrontal cortex on the psychomotor area, this commonly being followed by activity of one or more centres of special lower association, and often by that of the whole region of general lower association. Such are therefore regarded as normal products of thought of *personal* origin. The other normal, and in this case non-personal, mode of origin, which applies to all types of sensation, is of course that of sensory stimulation.

A third mode of origin of words, and also of other varieties of sensori-memorial image, is, however, common in normal persons; and if the mode is not more common, the results of it are at any rate more obtrusive in the subjects of mental disease. I refer to the spontaneous arising of words or other sensori-memorial images in the auditory or visual centres of lower association. From my experience of these phenomena in the subjects of mental disease, I have no hesitation in classing all such as hallucinations, which hallucinations may or may not be distinguished by the subject from true auditory or visual sensations. A homologous phenomenon to such a hallucination may be observed during the stimulation of the psychomotor area of a monkey which has recovered from anæsthesia. Such an animal regards the movement, say, of the arm with great surprise, and at once performs a voluntary and opposite movement, exactly as if the limb had been moved by an external agency. The resemblance between this response and the behaviour of a lunatic who is replying to "voices" is striking.

In the normal wide-awake condition such phenomena are, I believe, commonly discounted as memories or illusions; and when they occur during partial sleep or dreamy states and during sleep, the term "dream" is regarded as a sufficient explanation. In dreamy states these phenomena are very common, and are as a rule largely of a visual nature. In such, in my own case, whilst all kinds of complicated experiences occur in which I appear to take part, I have usually a more or less definite consciousness of personal aloofness from the phenomena, although, however impossible, they appear quite real. During sleep, on the other hand, this consciousness of personal non-participation is not present, and the phenomena, whether visual or auditory, whilst as a rule they are based on recent experience, often derive more of their content from the past. A very common experience of mine during the recent general election, when graphic representations of the state of parties appeared in the papers, was based on a combination of these illustrations and of my illustrations of cortical measurements. I seemed continually to be discovering that my measurements did not agree with my clinical cases, or that I had made mistakes in my deductions, only to find on awakening that I had been discovering columns indicating the state of the parties in my tables, or erroneously comparing such columns with my cases.

In some instances psychomotor activity ensues, and such persons may hear a reply to responses made to their remarks, and may even keep up a short conversation, of which they know nothing when they awake. Again, in the case of some persons, including myself, the first word or two spoken by the subject awaken him, and he remembers vividly what he has said and also the remainder of the phrase he was about to reproduce. On the other hand, many lunatics will talk to themselves, and reply to voices, for long periods of time, until their attention is attracted, after which they may revert to the former state of non-voluntary or semi-voluntary sensori-psychomotor activity.

Whilst most sane people interpret all such phenomena as "dreams," many instances nevertheless occur in which the subject, though otherwise sane, regards them as actual experiences of another world and strongly denies that he has merely been asleep and dreaming. In such cases credulity appears to be followed by belief, in a similar manner to that in which expectation results in increased sensitiveness to external impressions and often in the experience of illusions.

All these phenomena I regard as the homologues of, and as thus affording the explanation of, the more marked phenomena which are exhibited by the insane. Since such phenomena are in practice at times difficult to distinguish from, and in fact are often associated with, illusions, I shall refer to these before proceeding to remark on the subject of hallucination in the insane.

Illusions are common in sane individuals, and develop after a sensory stimulus which is of sudden occurrence and also either of short duration or of low intensity, especially when this stimulus is applied to a recognitive field which is in a hyper-excitable or expectant condition.

An example of the former is the sudden meeting, in a crowded street and under conditions which preclude a second and confirmatory sensory stimulus, of someone closely resembling a known individual. After such an experience, either doubt or certainty as to the correctness of the recognition may exist, although the individual seen may really have been a stranger; and in this case at least an illusion has been experienced.

The commonly cited example of the latter mode of development of an illusion is the recognition, in a faint illumination, of a window-blind or a white object as a ghost, which false recognition is, as a rule, readily corrected by further examination of the source of the sensory stimulus. It is perhaps, however, more common to meet with illusions of this type in the case of auditory stimuli, as when unexpected sounds are heard at night, or when certain expected footsteps or other sounds are being intently listened for. Such illusions are, as a rule, temporary. They cease if an increasing or a fading away of the auditory stimulus leads to the rejection of the false recognition; but they may persist if a fading away of the auditory stimulus occurs in association with a highly expectant condition of the recognitive field, and in the absence of additional and corrective visual or other sensory stimuli.

Illusions in the insane are similar in their psychic characteristics to those in the sane, but are more common, and on the whole are more likely to be accepted as true. This is especially the case when they occur in patients suffering from mental confusion or from dementia, for reasons which time does not permit me to dilate on.

A similar remark applies to hallucinations when occurring in the insane. It may in fact be stated that, considered generally, cases of amentia respond to illusions and hallucinations as do sane individuals, whereas cases of mental confusion or of dementia accept these as true without examination.

For instance, in certain examples of recurrent insanity these psychic phenomena do not suggest objective reality to the sufferer, who can, according to his degree of intelligence and his command of language, describe their characters and their modes of origin. As an illustration, I will cite the following remarks: "I thought my earthly father appeared in a flash under the fire-escape at the front. A man I was working with went under it and like as if he appeared to me in that man. That's where the idea sprang from." . . . "I hear my father's spirit at night, my earthly father's, guiding me, not like a voice but a spirit; whether it's a memory of his voice I don't know, like what I've heard him saying, sayings of his, and he tells me to believe in a God above, a Supreme above, and that he's in heaven, so it 'uld be a good job for me so long as he is safe in heaven—let me be safe, you know."

Again, a patient in a letter to me remarked: "I object to my muttered thoughts being known. I object to people being employed to pour nonsense into my ears. This treatment has a bad effect upon my nerves. It results in my muttered thoughts not invariably reflecting my views, desires, and intentions."

As a further instance, I will cite the following remarks of a man who was actively suicidal: "Evil thoughts overwhelm me which are wrong to God and me, evil thoughts about God even, which I don't believe in, as if an evil spirit was in me flashing an evil thought, if you understand what I mean. These thoughts have now, for the time being, become almost a part of myself, if you understand, and I feel the longer I am alive the greater is the punishment within myself, and the punishment in the future will be greater." From this description it would appear that the patient is gradually becoming more and more desperate owing to the activity of certain parts of his auditory zone of association, which spontaneously generates these particular verbal groupings he describes as thoughts.

In other examples of amentia, and especially in individuals who have little capacity for or habit of thinking, these phenomena possess a more or less objective reality, although by suitable interrogation it is, as a rule, easy to determine that the "voices" or experiences differ considerably in character from the normal products of the recognition of sensory stimuli. This difference is also evident from a consideration of the observation that the sufferers usually endeavour to determine the source of the phenomena, and, in their inability to do this, refer them to agencies of the action of which they are ignorant,—e.g., X-rays, telephones, cinematographs, &c.

On the other hand, in certain cases of mental confusion,—e.g., alcoholic confusion with marked tremor, which leads to aberrant visual stimuli, or confusion occurring in association with blocking of the external auditory meatus, or with disease or disorder of the middle ear, either of which may lead to the occurrence of aberrant auditory stimuli—the psychic phenomena are very largely caused by these aberrant sensory stimuli, although it is probable that in at any rate a large number of cases a definite part is played by deficiency or aberration of the processes of reproduction of associated memories under the influence of different aberrant sensory stimuli. Further, in many cases the sensory stimulus is probably relatively or entirely normal, but illusions result in consequence of certain associated memories, out of the enormous number of psychic units which may possibly be revived under the influence of external stimuli, being exceptionally liable to recrudescence. Whilst any of these psychic phenomena come under the definition of illusion, those of the latter type gradually shade into the phenomena which are regarded as hallucinations.

Lastly, examples of illusion and hallucination are common during actively progressing cerebral dissolution, as the result of the consequent riot of the processes of lower association which exists in patients suffering from this pathological condition of the cerebrum. Whilst to the observer these phenomena appear from the actions of the patients to possess an objective reality, it is probable in such cases that they are almost or entirely unaccompanied by consciousness, since in such cases extensive dissolution of the prefrontal centre of higher association has, as a rule, already taken place.

It is thus evident that illusion and hallucination grade from, on the one hand, the simple false recognitions of the normal sane individual, to, on the other, vivid associated memories which arise by processes of lower association, in the absence of sensory stimuli, and which, in the absence of control over the processes of cerebral association, may present such a resemblance to the psychic results of the recognition of sensorial stimuli as to be mistaken for these and projected externally.

Normal illusions thus occupy one end of the series, and the purely psychic phenomena described as hallucinations occupy the other, the numerous intermediate types of illusion possessing greater associational and less sensorial components until pure hallucinatory phenomena are reached.

Such psychic phenomena may occur as the result of a pathological process which is of a temporary nature or which will result in neuronic dissolution; they frequently, however, occur in the absence of active pathological conditions of the cortical neurones.

In the former case, particularly when the pathological process is widespread, considerable mental confusion exists and illusions may occur in association with aberrant sensory stimuli of any kind. It is usual, however, for visual illusions to predominate, because, in such patients, visual stimuli are, as a rule, the more numerous.

In the latter case—namely, in the absence of active pathological states of the cortical neurones, and in the consequent absence of mental confusion—the psychic phenomena, as a rule, occur at night, and are often precipitated by imperfect and aberrant auditory stimuli. The cause of this relative prominence of auditory psychic phenomena appears to be twofold. On the one hand, in at any rate most ordinary individuals, the usual channels for the reception and transmission of knowledge are hearing and speech, sight, except in the case of special psychic acquisitions, occupying a subordinate position. Further, the majority of persons think in words as spoken, rather than in words as seen. On the other hand, at night, and particularly during sleep, the higher cerebral processes are dormant or at their lowest ebb, and in consequence the processes of lower association, if active, are uncontrolled. Again, fear or apprehensiveness is naturally greater at night, or in the dark, than it is by day; and hearing, which is then the only sense available, is therefore preternaturally acute. It is thus possible to give a simple psychological explanation of the prominence of auditory illusions and hallucinations in such types of case as high-grade amentia and non-progressive dementia.

It is impossible here to do more than refer in the briefest manner to those more common symptoms of mental disease of which the physical bases may be relegated without hesitation to the centres of lower association. I shall therefore make no reference to the subject of delusion in the sane and the insane, or to that interesting and allied question, the recording of experience in a time-related manner. I have merely endeavoured to indicate, in more or less general terms, the relationship which I think exists between the normal processes of lower cerebral association and those which occur in the insane.

Whilst the linking together of such normal and abnormal processes of cerebral association cannot be regarded as evidence in favour of the particular partially proved provisional hypothesis of the cerebral functions which I have attempted to lay before you, such a comparison is, nevertheless, of interest in that it shows that the processes of cerebral association, whether of the sane or of the insane, are equally susceptible of explanation by means of it.

ADDENDUM.

The majority of the cases referred to in these lectures have already been published in previous communications. The essential details concerning these are contained in the following appendices, which also include detailed descriptions of the new cases.

For the use of Case C (Appendix A), a fœtus of 7 to 8 months, I am indebted to Dr. G. A. Watson, who has kindly lent me a series of preparations for photography and measurement. The illustrations of the precentral cortex of the dog, rhesus and man (figs. 62, 63 and 64) are also prepared from specimens lent to me by Dr. Watson.

Cases 1, 2, 3, 4, 5, 6, 7, 12, 13 and 16 (Appendix B) are new, and have been obtained at the Rainhill Asylum through the courtesy of Dr. Wiglesworth. The hemispheres illustrated on figs. 38 to 47 are also from cases who died at Rainhill Asylum. None of these photographs of hemispheres have been specially prepared. They have been selected from the systematic laboratory records—on the one hand because they were suitable cases, in the clinical course of which I was specially interested, and on the other because a series obtained in this manner exemplifies the ease with which abnormal and morbid appearances of the cerebrum may be studied when they have been systematically recorded.

I would remark that the method of recording intracranial appearances which I employed [7] whilst at Claybury Asylum has been adopted by Dr. G. A. Watson, who has used it at Claybury and subsequently at Rainhill. In a paper [26] published since these lectures were delivered, Watson has recorded his observations at Rainhill, and has compared his results with those obtained by myself at Claybury, arriving by a somewhat different mode of reasoning at substantially identical conclusions.

It is worthy of note that these conclusions of Watson have resulted from a study of morbid appearances alone, whereas the chief feature of my own papers was a correlation of the intracranial appearances found after death with the clinical features presented by the cases during life. I, therefore, trust that the definite relationship, which exists between the clinical evidences of amentia and dementia during life and the corresponding indications of cerebral sub-evolution and dissolution which are found after death, will in the future receive fuller recognition than has hitherto been bestowed upon it.

The preliminary acceptance of this general truth, followed by the combined clinical investigation of individual cases and macroscopic and microscopic study of the cerebra of these, is, I am convinced, essential as a scientific basis for the rational study of mental disease.

APPENDIX A.

THE FŒTAL AND INFANTILE BRAINS REFERRED TO IN FIGS. 20 AND 21.

Case A.—Male fœtus, aged a little over four months (fig. 11). Weight of the right hemisphere, after hardening in formalin, 32 grm. The prefrontal cortex of this case is shown in fig. 12.—*Archives of Neurology*, vol. ii., p. 571, Case 4.

Prefrontal Measurements. General average:—I, ·155; II—V, ·677. Total, ·832 mm.

Case B.—Fœtus, aged a little over six months (fig. 13). Weight of the left hemisphere, after hardening in formalin, 55 grm. The prefrontal cortex of this case is shown in fig. 14.—*Ibid.*, vol. ii., p. 572, Case 5.

Prefrontal Measurements. General average:—I, ·118; II, ·221; III, ·118; IV, ·221; V, ·221. Total, ·899 mm.

Case C.—Fœtus, aged between seven and eight months (fig. 15). Weight of the right hemisphere, after hardening in sublimate and formalin, 56 grm. The prefrontal cortex of this case is shown in fig. 16, and the visuo-sensory and visuo-psychic cortices in fig. 24.

Prefrontal Measurements.

Lamina	I	II	III	IV	V
Side (average of 13)	·071	·254	·128	·128	·175
Apex (average of 14)	·075	·360	·154	·200	·255
Bottom (average of 10)	·096	·217	·108	·075	·110
Flat (average of 28)	·072	·359	·155	·161	·216
General average (·841 mm.)	·078	·297	·136	·141	·189

Case D.—Right hemisphere of a stillborn male infant (fig. 17). Weight, after hardening in formalin, 194 grm. Left hemisphere, ditto, 196 grm. The prefrontal cortex of this case is shown in fig. 18.—*Ibid.*, vol. ii., p. 573, Case 6.

Prefrontal Measurements. General average:—I, ·188; II, ·434; III, ·154; IV, ·149; V, ·214. Total, 1·139 mm.

Case E.—Hemispheres of a stillborn female infant. Left, after hardening in formalin, 193 grm. Right, ditto, 190 grm.—*Ibid.*, vol. ii., p. 574, Case 7.

Prefrontal Measurements. General average:—I, ·217; II, ·575; III, ·178; IV, ·184; V, ·240. Total, 1·394 mm.

Case F.—Left hemisphere of an infant aged six months. Sex unknown. Died from marasmus. Whether this child was full-term or not it is, of course, impossible to state. It is possible, however, in view of the feeble and emaciated condition of the child, that its cerebral as well as its general bodily development had been retarded. Weight of the left hemisphere, after hardening in formalin, 161 grm.—*Ibid.*, p. 575, Case 8.

Prefrontal Measurements. General average:—I, ·188; II, ·520; III, ·174; IV, ·192; V, ·254. Total, 1·328 mm.

Case G.—Anophthalmos. Born of healthy parents and died from marasmus at the age of one month. The post-mortem was made forty-eight hours after death, in a small country cottage. The orbits were chink-like, and contained a little yellowish tissue at the back, which was apparently composed of fat. The eyelids were represented by small slits. No trace of either optic nerves or eyeballs could be discovered. A drawing of the visuo-sensory area is given as Case 6 in fig. 9.—*Phil. Trans.*, B191, 1900, p. 202.

Visuo-Sensory Measurements.—General average:—I, ·221; II, ·454; III*a* and III*b*, ·296; III*c*, ·223; IV, ·195; V, ·215. Total, 1·604 mm.

Visuo-Psychic Measurements. General average:—I, ·195; II, ·530; III, ·164; IV, ·254; V, ·208. Total, 1·351 mm.

Case H.—A perfectly healthy male infant, who died at the age of three months from broncho-pneumonia. A drawing of the visuo-sensory area is given as Case 5 in fig. 9.—*Ibid.*, p. 201.

Visuo-Sensory Measurements. General average:—I, ·243; II, ·428; III*a*, ·221; III*b*, ·241; III*c*, ·243; IV, ·141; V, ·202. Total, 1·719 mm.

Visuo-Psychic Measurements. General average:—I, ·242; II, ·676; III, ·191; IV, ·212; V, ·224. Total, 1·545 mm.

APPENDIX B.

NOTES OF THE THIRTY CASES REFERRED TO IN FIGS. 57 AND 58.

Case 1.—A male idiot who was admitted at the age of 10 and died at the age of 27. No history. Epileptic. " Cannot understand what is said to him, but stares vacantly when spoken to. Runs aimlessly about the wards and yards, and takes no notice of what is happening around. Laughs fatuously at anything, and performs monotonous, purposeless movements of the hands. Is inattentive to the calls of nature and cannot feed himself."

On admission was restless, wriggling about like an eel. Would not speak, but made inarticulate noises and said the word " yes " once, but not in any articulate sense. Was wet and dirty, and had to be dressed. He recognised people and showed a great variety of emotions—e.g., pleasure, anger, and grief.

A year before his death his condition had somewhat altered. Appearance vacuous, forehead receding, chin projecting. Hands cold and blue and showing signs of prolonged disuse. Skin rough. He made "negative " movements with his head almost constantly, and had a habit of balancing himself on one foot and the other alternately. In walking he shuffled along with his toes out and tended to drag the right foot. He did not understand what was said to him and could not speak. He could imitate the actions of other patients, but he had no idea of holding a pencil. He had a habit of making queer laughing noises through his shut lips. He could feed himself and used to grab at food. He was a " nice " boy, and showed none of the spitefulness so often seen in idiots, particularly when epileptic. He had 52 fits during the 15 months following his admission, and none during the following 18 years.

He died from tuberculosis of the lungs and intestines.

Encephalon 1133 grm., R.H. 490 grm., L.H. 485 grm., stripped 465 grm. Intracranial appearances natural apart from a moderate excess of subdural fluid. Brain below natural size, nearly proportionately developed, and of a convolutional pattern, which is rather below the average.

MICROMETRIC MEASUREMENTS OF CASE 1.

Visuo-Sensory.

Lamina	I	II	III			IV	V
			a	b	c		
Side	·183	·467	·153	·180	·245	·118	·189
Apex	·184	·355	·146	·217	·298	·166	·374
Bottom	·368	·421	·141	·127	·156	·059	·094
Flat	·125	·342	·144	·202	·292	·153	·280
General Average	·203	·396	·146	·182	·248	·124	·234
1·533 mm.				·576			

Visuo-Psychic.

Lamina	I	II	III	IV	V
Side	·175	·875	·237	·183	·255
Apex	·133	·751	·271	·318	·468
Bottom	·346	·655	·166	·081	·118
Flat	·153	·844	·247	·227	·321
General Average	·202	·781	·230	·202	·289

1·704 mm.

Case 2.—A male imbecile of moderate grade, with epilepsy. Admitted at the age of 12 and died at the age of 17 years. No history. "Imbecile. Claps his hands. Is 'boss' of this place. Does not know where he is. Laughs when spoken to. Very excited at times. Throws his boots at people. Unmanageable."

On admission was imbecile and fatuous. Possessed some memory and knew where he was, when he came, and the day of the week. Could remember being in another asylum for three years. Continually laughed, made grimaces and clapped his hands. Said that he had fits sometimes, and had had the last one two months ago.

Six months after admission he had 17 fits in a month, and four more during the next three months. He had no more fits until nine months before his death, when he had one. Before these fits he was a passably good boy, but afterwards he became more and more excitable, mischievous, troublesome and destructive, right up to the time of his death.

Two years before his death his condition was as follows:—Head small, especially in the frontal region. Vacant expression and the appearance of a child. Teeth pointed. A gap between the central incisors. He spoke with a lisp, and gave a fair but simple account of himself. He was fairly correct in his dates. He stated that he had been to school and had got into Standard II. 2 × 3 = 6, 4 × 3 = 9. He could not spell "cow," but then voluntarily remarked "c-a-t, cat." He slowly and painfully wrote his name, missing out the last vowel from each of the words. He seemed very pleased with this effort. He smiled pleasantly and seemed a very good and nice boy.

He was, however, one of the worst boys who had been in the asylum. He was filthy in his habits, untidy, destructive out of wantonness, very mischievous, and had quite a marvellous flow of foul language. He was by far the worst swearer in the asylum. He died from broncho-pneumonia and gangrene of the lungs, together with chronic dysentery.

Encephalon 995 grm., R.H. 444 grm., L.H. 440 grm., stripped 420 grm. There were no intracranial morbid appearances and the brain was considerably below the average size. The cerebellum weighed but 108 grm. The pattern of the cerebral hemispheres was generally simple, especially in the prefrontal region, and the sulci were generally shallow.

MICROMETRIC MEASUREMENTS OF CASE 2.

Visuo-Sensory.

Lamina	I	II	III			IV	V
			a	*b*	*c*		
Side	·165	·445	·147	·239	·290	·093	·181
Apex	·152	·317	·140	·240	·298	·158	·321
Bottom	·221	·395	·143	·208	·231	·074	·133
Flat	·108	·290	·150	·243	·290	·133	·228
General Average	·162	·362	·145	·231	·277	·115	·216
1·508 mm.				·658			

Visuo-Psychic.

Lamina	I	II	III	IV	V
Side	·187	·731	·227	·195	·258
Apex	·152	·728	·275	·317	·408
Bottom	·299	·602	·164	·087	·147
Flat	·144	·582	·218	·287	·349
General Average	·196	·661	·221	·222	·291

1·591 mm.

Case 3.—A male imbecile of moderate grade, with epilepsy. Admitted at the age of 26 and died at the age of 32. He was stated to have shown symptoms from the age of six years and he had been in a workhouse since the age of 20 years. No history. "Sullen, resentful, accusing all the inmates and attendants of abusing him (untrue), and wants to strike them. Kicks without warning all who approach him."

On admission was imbecile and very fatuous. Attention poor. Very incoherent and irrational. No idea of position and surroundings, and incapable of appreciating the lapse of time. Did not know where he was or whence he had come. No idea of the day of the week or the month. Could not tell his age. Knew that he took fits, but could not say when the last one occurred.

From a history which was subsequently obtained it appeared that when between 6 and 7 years of age he began to take fits. His education was neglected after this; and he ran about the streets, and had frequent and severe fits. He was always very simple-minded. He eventually became so mischievous that he had to be removed to the workhouse.

During his residence he had about 12 fits a month, which were rarely, if ever, followed by excitement. He was dirty and untidy and would not work. He was very violent at times, would strike out at anyone, and used often to smash plates and cups during meals. He could not, or would not, give any account of himself. He usually replied "nothing" or "nowhere" to questions, or gave such incoherent replies as "Oh, 38 T—— Street, not long. Seen Uncle John." He scrawled with a pencil, but made no attempt to write letters. He appeared to have no initiative as a rule, but it was impossible to be certain whether he was obstinate or simply dull. He died from pneumonia and gangrene of the lungs.

Encephalon 1180 grm., R.H. 515 grm., stripped 497 grm., L.H. 495 grm. Cerebellum 150 grm. No intracranial morbid appearances. The hemispheres were below the average complexity in pattern, and the sulci were shallow.

Since the death of this patient his brother has been admitted, suffering from an acute attack of mania without confusion. He is an excited, violent, impulsive and very dangerous case.

MICROMETRIC MEASUREMENTS OF CASE 3.

Visuo-Sensory.

Lamina	I	II	III *a*	III *b*	III *c*	IV	V
Side	·242	·492	·181	·264	·280	·103	·209
Apex	·149	·372	·153	·315	·320	·175	·339
Bottom	·339	·480	·164	·151	·178	·060	·122
Flat	·162	·402	·159	·324	·298	·180	·314
General Average	·223	·437	·164	·264	·269	·130	·246
1·733 mm.				·697			

Visuo-Psychic.

Lamina	I	II	III	IV	V
Side	·208	·654	·202	·169	·249
Apex	·141	·580	·232	·296	·382
Bottom	·348	·517	·134	·074	·133
Flat	·136	·505	·211	·273	·365
General Average	·208	·564	·195	·203	·282
1·452 mm.					

Case 4.—A male, suffering from a moderate grade of imbecility together with premature dementia. Admitted at the age of 21 and died at the age of 29. Was in an asylum from 15 to 18, and in a workhouse from 18 to 21. "Patient thinks people wish to do away with him by making him eat carbolic soap, and has tried to climb walls to get away because of the above. Is always shouting and crying."

He showed signs of phthisis on admission. He was imbecile and fatuous. He lay quietly in bed and submitted readily to examination. He was incapable of appreciating his position and surroundings or of accurately gauging the lapse of time. He could not tell where he was or whence he came, or the day of the week or the month. He answered very badly to questions and could give hardly any account of himself. He said that he had had fits for years. He stated that he had been in an asylum for five years and in a workhouse for three years, where an attendant encouraged him to drink the soap, and kicked him.

When he had got settled in the asylum he was restless, excited, talkative, and frightened. He could give a fairly good account of himself. He recognized some letters but could not read the simplest words. He could count up to 12 and name simple colours correctly. He could name ordinary articles.

He called a thermometer a "ventilator to tell the heat of the room." He could dress himself, but did not work.

Two years before his death his condition had somewhat changed. Lobules of ears adherent. Palate very high and shelving, and narrow. Teeth small and ground down. He keeps his hands in his pockets. He writes an unintelligible scrawl, which seems to be an imitation of writing by one who has never been able to properly learn. He has a lisp. He gives his name and many of the letters of the alphabet. 2 × 2? "Twice is 2, twice 2 is 2, twice is 2 2." 5 × 2? "Is six." 3 × 2? "Is 10, isn't it?" He went to school and got into the standard "where they draw the slates and sit at tables with pencils and write in copybook." Work? "I used to make brushmaking with wire on a vice and we used to . . . and I can glue in brushes what they sweep the floors with, with a handle to." Age? "Well, I don't know, well, I think, Sir, 60, over 60 I think, 80, 80." Here long? "I was here, I was here longest man in place. There wasn't a patient here when I come. There was only fields and no bricks, and no houses, and a man was knocking the door down with nails." He gives the day wrongly and also the date, saying, "16th, isn't it? Saturday, 16 October, April or May." He was excited and hysterical at times and was incapable of employment. He died from tuberculosis of the lungs and intestines.

Encephalon 1235 grm., R.H. 550 grm., L.H. 530 grm., stripped 514 grm. Cerebellum 150 grm. Moderate excess of fluid. Strips fairly readily. The cerebral hemispheres are below the average size and are a little below the average complexity of pattern, especially in the prefrontal region. There is slight and general fronto-parietal wasting.

Micrometric Measurements of Case 4.

Visuo-Sensory.

Lamina	I	II	III			IV	V
			a	*b*	*c*		
Side	·209	·567	·209	·255	·290	·106	·194
Apex	·177	·380	·152	·305	·320	·172	·336
Bottom	·289	·386	·156	·200	·214	·066	·186
Flat	·206	·449	·171	·334	·300	·199	·321
General Average	·220	·446	·172	·274	·281	·136	·247
1·776 mm.				·727			

Visuo-Psychic.

Lamina	I	II	III	IV	V
Side	·149	·626	·208	·153	·221
Apex	·103	·704	·247	·339	·449
Bottom	·312	·486	·138	·062	·102
Flat	·181	·884	·295	·298	·383
General Average	·186	·675	·222	·212	·289
1·584 mm.					

Case 5.—Female, widow, forewoman, aged 50. Duration before admission, 10 days. She died from infective endocarditis after a residence of 22 days. "Patient is in a state of acute mania. She screams and talks incoherently day and night. Has to be fed by force. Says she is the King's daughter."

Apical systolic murmur. Feeble health. Very noisy, incoherent and restless. Very resistive. Refuses food. Talks incessantly. Cannot give any account of herself. Is dirty in habits. Sleeps very little, and is very destructive to her bedding.

Encephalon 1245 grm., R.H. 540 grm., L.H. 535 grm., stripped 496 grm. Cerebellum 162 grm. Intracranial contents œdematous. Moderate excess of fluid. Membranes normal. Brain below average female weight. Pattern decidedly simple in the prefrontal region, and below the average in the parietal region.

MICROMETRIC MEASUREMENTS OF CASE 5.

Visuo-Sensory.

Lamina	I	II	III			IV	V
			a	*b*	*c*		
Side	·224	·496	·159	·299	·298	·143	·213
Apex	·131	·339	·140	·276	·318	·168	·376
Bottom	·318	·407	·141	·191	·199	·070	·112
Flat	·155	·526	·152	·292	·295	·166	·255
General Average	·207	·442	·148	·265	·278	·137	·239
1·716 mm.				·691			

Visuo-Psychic.

Lamina	I	II	III	IV	V
Side	·199	·825	·219	·183	·252
Apex	·174	·734	·242	·415	·501
Bottom	·337	·591	·155	·085	·130
Flat	·159	·731	·212	·197	·286
General Average	·217	·720	·207	·220	·292

1·656 mm.

Case 6.—Male, married, dock labourer, aged 25. Duration before admission five weeks. Died from pneumonia after a residence of 38 days. "Active melancholia. Profoundly depressed, actively suicidal, refuses to speak. Has recent marks on his neck from a knife."

Maternal grandmother had religious mania. Patient never touches drink. His nerves were upset owing to an accident 11 months ago, and he became melancholic and was always complaining about his stomach. He worried a good deal about his work and gave it up 5 to 6 weeks ago.

On admission patient had sordes on the lips and teeth, and a purulent discharge from the urethra. Very depressed. Takes no notice of anything, and occasionally makes a slight moaning noise. Is very restless and often tries to get out of bed, struggling aimlessly if interfered with. He gives his name in a whisper, but no further replies to questions. He takes no notice of food, but swallows it when fed with a spoon. He is clean in his habits. Two days after admission patient tried to strangle himself with a scarf. A week later he was very dull, depressed and agitated. He resisted everything done for him and needed treatment in the padded room. He frequently called out the same phrases over and over again. At the time of his death he showed slight mental improvement.

Encephalon 1570 grm., R.H. 695 grm., L.H. 690 grm., stripped 652 grm. Cerebellum 175 grm. Slight excess of fluid. Strips readily. The brain is considerably above the average size. There is decreased development of the prefrontal region, and asymmetry on the two sides with regard to the relative development of the different regions of association. On the whole the pattern is below the average complexity.

MICROMETRIC MEASUREMENTS OF CASE 6.

Visuo-Sensory.

Lamina	I	II	III			IV	V
			a	*b*	*c*		
Side	·200	·467	·159	·252	·292	·187	·228
Apex	·219	·446	·152	·283	·300	·215	·384
Bottom	·271	·435	·144	·173	·219	·080	·147
Flat	·205	·426	·153	·255	·295	·180	·288
General Average	·224	·444	·152	·241	·277	·153	·261
1·752 mm.				·670			

Visuo-Psychic.

Lamina	I	II	III	IV	V
Side	·196	·754	·222	·161	·242
Apex	·203	·732	·253	·340	·505
Bottom	·321	.572	·150	·074	·133
Flat	·222	·913	·280	·262	·359
General Average	·236	·743	·226	·209	·310

1·724 mm.

Case 7.—Female, single, servant, aged 30. Duration before admission two weeks. Died from cancer of the lung after a residence of nine months. Parents both intemperate.

Thirteen years ago patient had an attack of melancholia, and was treated in the workhouse. Since that time she has been a general servant, has kept well, and has worked steadily. She suddenly became noisy and excited about two weeks before admission. "Noisy, excited and incoherent. Requires to be restrained, and is trying to be free. Violent, noisy and dirty."

On admission, the patient, who is a nullipara, was very restless, emotional and excited. She made grimaces, gesticulated, and was quite incoherent. When asked to write her name she took the pencil and wrote her initials, but then at once broke away and scrawled all over the paper, at the same time laughing and talking incoherently. She was extremely emotional, laughing and crying by turns, and using foul language very frequently. She noticed everything around her and frequently repeated what she happened to hear. At times she listened as if to voices, and made such remarks as "You're a liar," "I never was drunk in my life," "Mother's over there." At times she threw crockery and struggled if prevented. She was very noisy at night, singing and shouting. She was very troublesome and resistive over her food, and she was wet and dirty in her habits.

Towards the time of her death, though she was still excitable, and noisy at night, and appeared to suffer from hallucinations of hearing, she was often quite sensible. She talked intelligently to her friends. She asked the nurses for forgiveness for all she had said and done to them. She was very clean in her habits, and, when more feeble, used to get into an awful state if she happened unavoidably to "make a mistake." From the beginning to the end of her illness, whilst at first all the nurses with whom she was in contact could not get on with her, they invariably ended in being extremely fond of her.

Encephalon 1555 grm., R.H. 670 grm., L.H. 672 grm., stripped 645 grm. Slight excess of fluid. Pia stripped rather more readily than natural. Cerebellum 195 grm. The brain was much above the average female size. The cerebrum was very complex, and many secondary gyri were present.

MICROMETRIC MEASUREMENTS OF CASE 7.

Visuo-Sensory.

Lamina	I	II	III			IV	V
			a	*b*	*c*		
Side	·261	·629	·227	·346	·308	·144	·242
Apex	·197	·446	·166	·355	·318	·214	·415
Bottom	·306	·535	·150	·202	·211	·078	·122
Flat	·239	·595	·186	·230	·295	·141	·230
General Average	·251	·551	·182	·283	·282	·144	·252
1·945 mm.				·747			

Visuo-Psychic.

Lamina	I	II	III	IV	V
Side	·222	·935	·253	·208	·284
Apex	·166	·829	·261	·370	·520
Bottom	·331	·567	·152	·088	·140
Flat	·161	·950	·273	·321	·420
General Average	·220	·820	·235	·247	·341
1·863 mm.					

Case 8.—Male, aged 55. Normal.—*Phil. Trans.*, B 191, 1900, page 188, Case 1.

Micrometric measurements of Case 8:—

Visuo-Sensory. General average:—I, ·254; II, ·523; III*a*, ·218; III*b*, ·215; III*c* ·289; IV, ·142; V, ·240. Total, 1·881 mm.

Visuo-Psychic. General average:—I, ·274; II, ·864; III, ·200; IV, ·229; V, ·293. Total, 1·860 mm.

Case 9.—Female, aged 17. A case of epileptic dementia.—*Ibid.*, page 192, Case 2.

Micrometric measurements of Case 9:—

Visuo-Sensory. General average:—I, ·227; II, ·423; III*a*, ·224; III*b*, ·238; III*c*, ·299; IV, ·146; V, ·265. Total, 1·822 mm.

Visuo-Psychic. General average:—I, ·248; II, ·778; III, ·207; IV, ·213; V, ·290. Total, 1·736 mm.

Case 10.—Female, aged 27. A case of blindness from infancy, and chronic insanity with dementia.—*Ibid.*, page 195, Case 3.

Micrometric measurements of Case 10:—

Visuo-Sensory. General average:—I, ·235; II, ·396; III*a*, ·198; III*b*, ·112; III*c*, ·270; IV, ·120; V, ·250. Total, 1·581 mm.

Visuo-Psychic. General average:—I, ·250; II, ·791; III, ·222; IV, ·182; V, ·297. Total, 1·742 mm.

Case 11.—Male, aged 30. A case of long-standing blindness, and chronic insanity with dementia.—*Ibid.*, page 198, Case 4.

Micrometric measurements of Case 11:—

Visuo-Sensory. General average:—I, ·281; II, ·418; III*a*, ·193; III*b*, ·136; III*c*, ·291; IV, ·129; V, ·219. Total, 1·667 mm.

Visuo-Psychic. General average:—I, ·289; II, ·768; III, ·178; IV, ·194; V, ·248. Total, 1·677 mm.

Case 12.—Male, single, packer, aged 23. Maternal aunt in an asylum. Mother dull and slow, and of poor memory. Father and mother intemperate. Youngest sister left school at the age of 14 after entering Standard VI. Patient was in Standard VI at the age of thirteen and-a-half, and then refused to go to school any longer. He was then in Ireland for six months, was then for six months in a printing works, and was afterwards in a mill for five years. He then suffered from appendicitis, but did not require operation. After leaving the hospital he worked at a mill until three days before admission to the asylum. "When he came home from work, he started laughing and acted in a silly manner." He did not drink.

"Delusions that he is being transformed into a 'Jap.' Uses foul language when spoken to. Shakes his fist at the skylight as if threatening someone. Excited, noisy, violent, and refuses food at times. Dirty."

On admission he was pale and thin. Ears plain. Pinnæ large. Palate high. Alveolus very thick. Slight double internal strabismus. Phimosis. Excited, restless, noisy and garrulous. Gesticulates and strikes attitudes. Slaps the bed and parts of his body. Very theatrical in behaviour. Talks about "God," "Man-God," and "Buffalo Bill holding the whole world in his hand." A sequence of ideas can be traced. He gives his name and age, and adds "twenty-two summers, never known death and never will," and then talks about Father, Son, and Holy Ghost, &c. At times he answers questions, and at others does not. His attention can be attracted for the moment, and then after replying he becomes inconsequent, and afterwards incoherent. Day? "My birthday, 22 December." Where are you? "I'm in Liverpool now, Scotland Yard. Detective." Name of head attendant? "Mr. Steward or some great man at B——. I being a scamp and a fool along the docks. Another Christian man. All Christianity has been a blaspheming from beginning to end." He is restless, noisy, impulsive, and wet and dirty. He sleeps and takes his food.

During the first month after his admission he made several temporary recoveries. A week later he tied a scarf tightly round his neck. Three months after his admission he was constantly restless, excited, incoherent, monkey-like, and unemployed. He then gradually improved during five months, and became a worker. Eight months after his admission he gradually developed stupor. He spoke slowly and with a long latent period. His face became greasy and expressionless. At times, when spoken to, he appeared to brighten up, but soon relapsed into stupor. He remained in this condition until his death, eighteen months after admission, becoming cold and blue and thin, and eventually dying from marasmus.

Encephalon 1435 grm., R.H. 605 grm., stripped 570 grm., L.H. 608 grm. Cerebellum 215 grm. Intracranial morbid appearances of moderate intensity, (Group III). Smaller cerebral vessels wiry. Hemispheres of average size but below average complexity. Gyri generally large. Some prefrontal wasting,

MICROMETRIC MEASUREMENTS OF CASE 12.

Visuo-Sensory.

Lamina	I	II	III			IV	V
			a	*b*	*c*		
Side	·246	·527	·171	·217	·267	·127	·208
Apex	·199	·471	·166	·247	·298	·188	·350
Bottom	·306	·471	·140	·162	·180	·066	·107
Flat	·199	·527	·155	·239	·295	·177	·269
General Average	·238	·499	·158	·216	·260	·140	·284
1·745 mm.				·634			

Visuo-Psychic.

Lamina	I	II	III	IV	V
Side	·242	·809	·208	·180	·249
Apex	·169	·744	·230	·289	·431
Bottom	·328	·652	·133	·074	·140
Flat	·183	·787	·222	·267	·330
General Average	·231	·748	·198	·203	·288
1·668 mm.					

Case 13.—Male, single, plumber, aged 44. No history. "Memory a blank. Can remember nothing that has happened. Does not know when he had food last. He says that he has had none to-day and that he has not much inside left. Depressed and silent and takes little notice of anything."

On admission: Palate high and shelves forwards. Face expressionless. Speech occasionally slurred. Knee-jerks absent. Pupils below medium and react rapidly to light and accommodation. Early tuberculosis of lungs.

Dull and apathetic. Gives his name. Age, "63 . . . 61, I beg your pardon." Knows neither the day, the date, the month, nor the year. Does not know when he came. At different times he gave his age as "63 come Christmas," "35," and says he was born in the year "1860" (correct). He denies venereal disease, having been "one of the lucky ones." He says that he has always come off "second best at anything I've tackled." He has drank a good deal. At times he brightens up during conversation, but he rapidly lapses into silence and he never volunteers a remark. He appears not to suffer from either illusions or hallucinations.

Six months after admission he was dull and took little interest in his surroundings. He could give no account of recent events. His conversation was coherent, but his memory, especially for recent matters, was very poor. In the month of November he thought that it was summer. He remarked that his memory was bad, but that it was slowly coming back again.

Six months later he gave his age as 60. He stated that he came a fortnight ago, and was ignorant of such recent events as even an ordinary case of dementia might have been expected to remember. He knew me but not my name, although he had known me well since his admission.

He died from tuberculosis of the lungs and intestines twenty-one months after admission, at which time he was practically a skeleton. He exhibited well-marked but not gross dementia, which was, however, unusually profound for a man of his age who did not suffer from general paralysis.

Encephalon 1260 grm., R.H. 525 grm., L.H. 522 grm., stripped 488 grm. Cerebellum 178 grm.

Enormous excess of fluid. Pia stripped extremely readily. Cerebral hemispheres—below the average size, and perhaps so even when wasting was allowed for; proportionately developed; rather below the average complexity. Convolutions rather small, especially in the prefrontal region. Wasting very marked in the fronto-parietal and upper temporal regions, but especially severe in the prefrontal region. The wasting appears to be of an unusually pure neuronic type, since the cerebral vessels, large and small, are quite normal. A recent subdural deposit of the thickness of brown paper.

MICROMETRIC MEASUREMENTS OF CASE 13.

Visuo-Sensory.

Lamina	I	II	III			IV	V
			a	*b*	*c*		
Side	·228	·617	·209	·299	·295	·177	·278
Apex	·166	·486	·151	·357	·318	·230	·407
Bottom	·331	·465	·147	·172	·206	·075	·124
Flat	·155	·445	·155	·300	·305	·191	·298
General Average	·220	·491	·166	·282	·281	·168	·276
1·884 mm.			·729				

Visuo-Psychic.

Lamina	I	II	III	IV	V
Side	·197	·798	·240	·171	·236
Apex	·175	·794	·274	·362	·516
Bottom	·380	·613	·158	·094	·137
Flat	·189	·815	·250	·254	·362
General Average	·235	·755	·231	·220	·313

1·754 mm.

Prefrontal.

Lamina	I	II	III	IV	V
Side	·225	·694	·284	·181	·256
Apex	·141	·681	·277	·387	·482
Bottom	·320	·566	·180	·092	·143
Flat	·146	·608	·250	·306	·409
General Average	·208	·637	·235	·242	·323

1·645 mm.

Case 14.—Female, aged 36. A case of well-marked imbecility. Brain rather small but perfectly natural, except for slight simplicity of pattern and a somewhat decreased development of the prefrontal region. Weight 1165 grm. —*Archives of Neurology*, vol. ii., p. 579, Case 9.

Prefrontal Measurements. General average :—I, ·209 ; II, ·526 ; III, ·163 ; IV, ·189 ; V, ·257. Total, 1·380 mm.

Case 15.—Female, aged 24. A case of well-marked imbecility with epilepsy, of a rather milder grade than the preceding case. Cerebrum very small, 660 grm. Pattern fairly normal. Marked mycrogyria in the upper third of the external surface of each hemisphere near the median fissure but not involving the median portion of the hemispheres. The cuneus is represented by a single gyrus, and the cuneal annectant runs superficially into the cingulate gyrus.—*Ibid.*, p. 582, Case 10.

Prefrontal Measurements. General average :—I, ·253 ; II, ·607 ; III, ·193 ; IV, ·215 ; V, ·281. Total, 1·549 mm.

Case 16.—A male macrocephalic imbecile of moderate grade. Age unknown, but probably about 50. Had been certified 37 years at death, and was in the present asylum fourteen years. Height, 58½ in. Circumference of head, 23¼ in. Small body and limbs. Childish and of low intelligence. Vocabulary limited, and the words used to express his wants are indistinctly uttered and helped out for the comprehension of others by signs. Fond of attention. Voracious and eats ravenously and rapidly. Clean in habits when watched, but requires tending. He could dress himself. He was destructive and impulsive and fond of annoying feeble old men who might be expected to be unable to retaliate. He used to shout when an officer entered the ward, and was accustomed to ask for a basin of tea before going to bed. He was a favourite with the staff, who taught him to sing songs and to repeat new words. He died from mitral stenosis and gangrene of the lung.

Encephalon 1775 grm., R.H. 816 grm., stripped 775 grm., L.H. 775 grm., stripped 747 grm. Cerebellum, 180 grm. White matter firmer than normal. Corpus callosum short and thick. Intracranial morbid appearances slight or absent (Group I-II). Arrangement of gyri very complex and very irregular. Sulci deep. Convolutions of good size and breadth, with the exception of the frontal and parietal regions, where some are very good and some are very poor. The parietal region is relatively very small, as are also the gyri in this region. The normal distribution of the main sulci cannot be made out, as these are largely replaced by numerous curved gyri.

Prefrontal Measurements. General average:—I, ·278; II, ·663; III, ·212; IV, ·236; V, ·295. Total, 1·684 mm.

Case 17.—Female, aged 11. A case of mild imbecility with epilepsy who might have been capable of considerable improvement under proper training. Encephalon 1100 grm. Some under-development of the prefrontal region near the midline, most evident in the left hemisphere. This is not marked, and on ordinary examination the brain would readily pass for normal. *Archives of Neurology*, vol. ii., p. 583, case 11, right hemisphere.

Prefrontal Measurements. General average:—I, ·276; II, ·729; III, ·201; IV, ·193; V, ·272. Total, 1·671 mm.

Case 18.—Ditto. Left hemisphere.

Prefrontal Measurements. General average:—I, ·290; II, ·770; III, ·199; IV, ·199; V, ·274. Total, 1·732 mm.

Case 19.—Female, aged 56. A case of recurrent insanity of a duration of fifteen days in the asylum, and perhaps a few months outside. Brain normal, weight 1185 grm.—*Ibid.*, p. 591, Case 13.

Prefrontal Measurements. General average:—I, ·261; II, ·701; III, ·212; IV, ·216; V, ·302. Total, 1·692 mm.

Case 20.—Female, aged 49. A case of chronic insanity without dementia. Brain normal apart from an old-standing softening in the right hemisphere, probably due to embolic occlusion of the middle cerebral artery. Encephalon 1115 grm.—*Ibid.*, p. 592, Case 15.

Prefrontal Measurements. General average:—I, ·259; II, ·723; III, ·212; IV, ·209; V, ·293. Total, 1·696 mm.

Case 21.—Female, aged 36. A case of chronic insanity with little or no dementia. Cerebrum 1235 grm. Very slight intracranial morbid appearances. Hemispheres normal. *Ibid.*, p. 591, Case 14.

Prefrontal Measurements. General average:—I, 264; II, ·754; III, ·231; IV, ·229; V, ·308. Total, 1·786 mm.

Case 22.—Female, aged 36. Normal. Cerebral small and underdeveloped. Unstripped hemispheres, after hardening in formalin, weighed but 469 and

465 grm. The case may have been one of potential insanity, especially as no history of insanity was looked for.—*Ibid.*, p. 566, Case 3.

Prefrontal Measurements. General average :—I, ·283; II, ·756; III, ·226; IV, ·232; V, ·317. Total, 1·814 m.m.

Case 23.—Female, aged 38. Normal. After hardening in formalin, the right hemisphere weighed 539 grm., and the left 515 grm., both unstripped.—*Ibid.*, p. 565, Case 1.

Prefrontal Measurements. General average :—I, ·277; II, ·836; III, ·241; IV, ·236; V, ·302. Total, 1·892 mm.

Case 24.—Male, aged 13. Normal. Stated to be deaf and dumb. After hardening in formalin, R.H. weighed 577 grm., and L.H. 568 grm.—*Ibid.*, p. 566, Case 2.

Prefrontal Measurements. General average :—I, ·341; II, ·901; III, ·220; IV, ·223; V, ·310. Total, 1·995 mm.

Note.—As an increase in weight, to the extent of about 10 per cent., takes place during the process of hardening in formalin, the above three normal cases (Cases 22, 23, and 24) all have brain weights which are well below the average, and are consequently likely to give micrometric results which are below rather than above the average normal.

Case 25.—Male, aged 37. A case of imbecility with mild dementia. Slight intra-cranial morbid appearances. Encephalon 1305 grm.—*Ibid.*, p. 588, Case 12.

Prefrontal Measurements. General average :—I, ·252; II, ·674; III, ·208; IV, ·200; V, ·290. Total, 1·624 mm.

Case 26.—Female, aged 59. A case of mania with marked dementia. Intracranial morbid appearances of moderate intensity (Group III). Encephalon 1220 grm. Cerebral wasting which is marked in the prefrontal region, moderate in the fronto-parietal region and the first temporal gyrus, and slight or absent elsewhere.—*Ibid.*, p. 598, Case 16.

Prefrontal Measurements. General average :—I, ·248; II, ·698; III, ·202; IV, ·208; V, ·292. Total, 1·648 mm.

Case 27.—Female, aged 53. A case of severe dementia. Well-marked intracranial morbid appearances (Group IV). Encephalon 1112 grm. Cerebral wasting which is very severe in front of the ascending frontal gyrus, and moderate over the rest of the fronto-parietal region and the first temporal gyrus, being slight or absent elsewhere.—*Ibid.*, p. 599, Case 17.

Prefrontal Measurements. General average :—I, ·257; II, ·607; III, ·218; IV, ·225; V, ·293. Total, 1·680 mm.

Case 28.—Female, aged 78. A case of gross dementia. Gross intracranial morbid appearances (Group V). Encephalon 1175 grm. Cerebral wasting, which is very marked in the prefrontal region, well marked in the fronto-parietal region and the first temporal gyrus, and less marked elsewhere.—*Ibid.*, p. 600, Case 18.

Prefrontal Measurements. General average:—I, ·238; II, ·688; III, ·213; IV, ·197; V, ·255. Total, 1·591 mm.

Case 29.—Female, aged 53. A case of gross dementia with Huntington's chorea. Gross intracranial morbid appearances (Group V). Encephalon 1025 grm. The cerebrum shows wasting which is very extreme in the prefrontal region, marked in the fronto-parietal region and the first temporal gyrus, and moderate elsewhere.—*Ibid.*, p. 603, Case 19.

Prefrontal Measurements. General average: I, ·297; II, ·631; III, ·182; IV, ·174; V, ·226. Total, 1·510 mm.

Case 30.—Male, aged 41. A case of gross dementia paralytica. Gross intracranial morbid appearances, together with the usual signs of general paralysis. Encephalon 1280 grm. The brain, after hardening in formalin, cuts like soft wood. The wasting is very extreme in the prefrontal region, it is marked in the central convolutions, it is marked and the morbid process is acute in the parietal region and the whole of the temporo-sphenoidal, and it is moderate in the rest of the cerebrum.—*Ibid.*, p. 608, Case 20.

Prefrontal Measurements. General average:—I, ·274; II, ·682; III, ·168; IV, ·142; V, ·201. Total, 1·467 mm.

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DOES POLIOMYELITIS OCCUR DURING INTRA-UTERINE LIFE?

BY FREDERICK E. BATTEN, M.D.

INTRODUCTION.

THE object of this paper is to discuss the possibility of the infection of a child with poliomyelitis whilst still *in utero* and to bring forward some evidence that such infection does occur. It must be admitted that there is great difficulty in the differential diagnosis of cases of injury to the nerves of the brachial plexus and of hæmorrhage into the grey matter of the spinal cord of new-born infants from cases of poliomyelitis.

The cases submitted for consideration are cases in which a pathological examination has shown that the condition is due to a lesion of the spinal cord, and had fallen with special incidence on the grey matter of the ventral horns.

Flaccid paralysis of one arm due to birth-injury is far from uncommon in infants, and it has been shown by Herbert Spencer [5] that hæmorrhage into the grey matter of the spinal cords of children dying at birth or soon after delivery is not uncommon. That some of these latter cases in which the hæmorrhage has been less extensive might live has to be considered, and I have seen a case in which such a lesion seemed probable; but I have never been able to prove the condition by pathological examination.

I have only been able to find one reference in the literature to the occurrence of fœtal poliomyelitis, and that is a case published by Fritsch, of Breslau [3]. In that case the child was born without injury, but the birth was a breech presentation. The child had paralysis of both upper and lower extremities. There was a complete atrophic paralysis of both arms, with great loss of electrical excitability, whilst the legs were abducted to the fullest extent at the hips, flexed at an acute angle at the knee, so that the clumped feet lay opposed to one another. The muscles of the legs were not atrophic and responded normally to electrical stimulation. On clinical grounds alone I should not be prepared to consider the probability of this case being one of poliomyelitis; the spastic condition of the legs is a most unusual symptom in poliomyelitis, and it is one which is extremely likely to occur after a traumatic lesion of the cervical region of the spinal cord. This case is not confirmed by any pathological examination, and therefore may be left aside.

From time to time cases of paralysis in infants have come under observation which from their clinical features suggest the diagnosis of poliomyelitis, and in which the condition is said to have been present at, or immediately after, birth.

Such a history suggests the possibility of an intra-uterine poliomyelitis; it is but seldom, however, that an opportunity arises of proving such a condition by a pathological and microscopical examination. The two cases about to be narrated are of different value from the clinical point of view, for the first was seen when two years old and watched for several years, and always regarded as a case of intra-uterine poliomyelitis; the second, although the paralysis was stated to be present at birth, yet on careful inquiry it was found that the child had not been cared for by its mother during the whole period, but had been in an infirmary: the history is therefore not trustworthy.

CLINICAL AND PATHOLOGICAL EXAMINATION OF CASE 1.

The first case is that of a boy, who, when first seen at the Children's Hospital, Great Ormond Street, in November, 1900, was two years old. The mother, a careful woman, and one whose evidence can, I think, be accepted, gave the following history:—

The child was the second of two children, the first being quite healthy.

At birth it was noticed that the child had weakness of the left arm, but no weakness of the legs was noticed until between the first and second years of life, when the child should have made some attempt to stand.

The birth was natural, but very rapid—labour lasting only twenty minutes—and the child fell from the bed on to the floor. The mother had no illness whilst carrying the child.

There was no history of acute illness during the child's life, and he had had none of the acute specific fevers.

On examination, the child was small and delicate, but of normal intelligence. He could talk, but was quite unable to walk. He could sit up, and used his right hand and arm well. His back was straight.

The left arm hung flaccid from the shoulder, and he had complete paralysis of the left deltoid and biceps, with weakness of the triceps and supinator longus. The muscles of the forearm and hand were relatively well developed, and all movements were capable of being performed. The paralysed muscles were quite flaccid and the head of the humerus hung away from the glenoid cavity. There was some wasting of the scapular muscles.

Both legs were weak, but the right was much more affected than the left, the skin was blue and cold, and in this particular also the right was more affected than the left. The muscles of the right leg were wasted, and especially so below the knee; the gastrocnemius was almost powerless, and the foot assumed a position of pes calcaneus. There was general flaccidity of this limb. The muscles of the left leg were also flabby and weak, but not to so great an extent as the right leg. The boy could support the weight of the body on the left leg. The knee-jerk was present on the left side, but on the right only a very slight contraction of the quadriceps extensor could be obtained.

The plantar response on the left side was flexor, but on the right a very definite extensor response was obtained (it seemed probable that the extensor response was dependent on the fact that the extensor muscles were comparatively well preserved, whereas the flexors were greatly affected).

Sensation over the trunk and limbs was perfect.

Electrical Reaction.—No reaction to faradism was obtained in the left deltoid, a very feeble contraction in the left biceps; the left supinator longus acted fairly. The muscles of the right arm reacted well.

Clinically the case appeared exactly like an extensive poliomyelitis, affecting both legs and the left arm, and had it not been for the history it would have been considered as a severe result of such a condition.

From November, 1901, until 1908, when the boy contracted diphtheria, he was constantly under my care.

He gradually learnt to walk, at first without any instrumental support, and after 1905, with the aid of an instrument, he was able to get about fairly well. His general health improved, but he always remained a thin and poorly nourished child. The shoulder-muscles of the left arm never regained any power.

In January, 1908, when eight years old, he contracted diphtheria, from which he died. With some difficulty permission was obtained to examine the brain and spinal cord, and a post-mortem was performed in the Western Fever Hospital, thirty-six hours after death. The weather was cold, and the body was in good preservation. The membranes of the brain and spinal cord appeared normal on naked-eye examination. After hardening, the cord was carefully examined. All the dorsal roots appeared normal and of good size. On examining the ventral roots, it was obvious that those coming from the fifth cervical segment on the left side were smaller and greyer than those on the right side. The difference between the other cervical roots on the left side as compared to the right was not obvious. In the lumbar and sacral region again, although the roots appeared somewhat smaller than normal, yet no marked difference could be made out between the two sides.

MICROSCOPICAL EXAMINATION.

The cord, after being hardened, was cut and stained by Van Gieson and Weigert-Pal methods. Sections were taken at various levels in the cervical, thoracic, lumbar, and sacral region of the cord.

Four typical sections will be described: (1) At the level of the fifth cervical segment; (2) at the level of the twelfth thoracic; (3) at the level of the third lumbar; and (4) at the level of the second sacral.

Van Gieson's Method.

(1) At the level of the fifth cervical segment the most striking change which is manifest is the very marked diminution in the number of cells in the region of the left ventral horn. The lateral portion of the ventral horn is that which is most affected—a small group of normal cells is seen in the ventral mesial group. On the right side the cells of the ventral horn are more numerous, but even here, as compared to a normal cord, it would be said that the cells were less numerous and smaller than normal.

No recent inflammatory change can be detected, nor is there any great increase of connective tissue, or remains of inflammatory products in the region of the horns.

(2) At the level of the twelfth thoracic segment there is a great diminution in the number of cells in the ventral horn on both sides, only one or two normal cells can be seen. The cells of Clarke's column are well developed on the one side, but are almost absent on the other.

The ventral roots as they pass through the white matter are most poorly developed, and form but a small bundle after they leave the cord, and are in this respect in striking contrast to the dorsal roots.

(3) At the level of the third lumbar segment there is a great diminution in the number of cells in the ventral horn on both sides; a few scattered cells are present. The ventral roots are most poorly developed.

(4) At the level of the second sacral segment there are one or two well-developed groups of cells, but the relative number of cells is greatly diminished.

Weigert-Pal Method.

At the level of the fifth cervical segment (fig. 1) the left side of the cord is obviously smaller than the right. The whole of the antero-lateral tracts, with the exception of the dorsal and ventral cerebellar tracts, are paler than normal. The grey matter on the left side is somewhat smaller than on the right, but the diminution of the medullated fibres in the grey matter on the left side is the most striking feature.

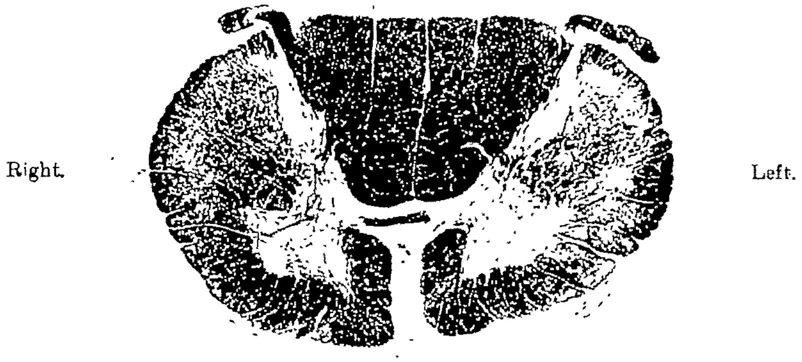

FIG. 1.

Section from the spinal cord at the level of the fifth cervical segment (stained by the Weigert-Pal method) showing diminution in size of the left side of the spinal cord, paleness of the fibres in the antero-lateral tracts, and a diminution in the number of the medullated fibres of the grey matter.

At the level of the first lumbar segment (fig. 2) the left side of the cord appears to be smaller than the right, and the grey matter of the ventral horn on that side is also smaller than that on the right side. The same paleness of the antero-lateral tracts is present as in the cervical segment; it is, however, more marked than in the cervical region. The absence of medullated fibres in the ventral horns is also a striking feature.

At the level of the third lumbar segment (fig. 3) there is in both ventral horns a patch in which almost all medullated fibres appear to be absent. The medullated fibres in the other portions of the grey matter of the anterior horn are diminished in number, being on the whole better preserved on the left side than on the right.

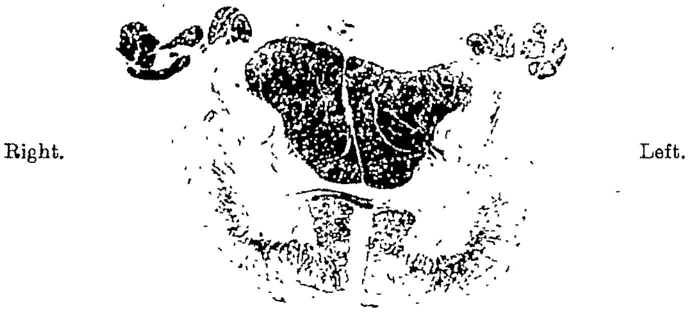

FIG. 2.

Section of the spinal cord at the level of the first lumbar segment (stained by the Weigert-Pal method) showing diminution in size of the ventral horn on the left side, and also a great diminution of the medullated fibres both in the grey and white matter of the cord.

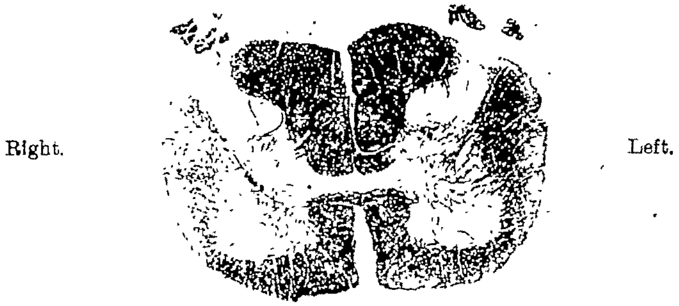

FIG. 3.

Section of the spinal cord at the level of the third lumbar segment. The ventral horn of the left side is seen to be smaller than the right, but the most striking feature is the absence of medullated fibres in an area on the outer side of the right ventral horn, and also of a similar area in the left ventral horn.

At the level of the second sacral segment (fig. 4) the diminution in the size of the cord on the left side is very obvious; on the other hand, there is a patch in the grey matter on the right side, in which nearly all the medullated fibres are absent.

The paleness of the antero-lateral tracts, as compared to the posterior columns, is very marked.

Shortly, it may be said that the most striking features are: (1) The diminution in size, not only of the cord, but also of the grey matter in the regions affected. (2) The presence of areas in the ventral horns in which there is an almost complete absence of medullated fibres. (3) The absence of large cells in the ventral horns of the regions of the spinal cord most affected. (4) The diminution in the size of certain ventral roots. (5) The paleness of the antero-lateral tracts.

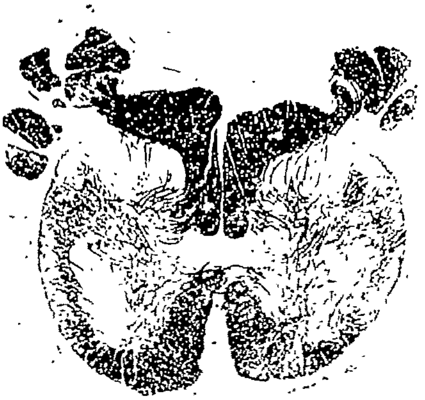

FIG. 4.

Section of spinal cord at level of second sacral segment. The left side of the cord is seen to be smaller than the right, but in the grey matter of the right ventral horn there is seen to be an elongated patch, in which there is an almost complete disappearance of medullated fibres.

The condition is exactly similar to that found in late cases of poliomyelitis [1].

CRITICISM.

I am fully aware that the above case is open to criticism, and the points that could be urged against the acceptance of this case as one of intra-uterine poliomyelitis are: (1) That the acute onset occurred after birth, and escaped the notice of the mother. (2) That the condition is due to hæmorrhage into the grey matter of the spinal cord at the time of birth, resulting either from the rapid labour or the fall at birth. (3) That the condition is due to a developmental defect. (4) That the condition is due to an extensive and severe injury to the peripheral nerves, with consecutive atrophy in the cells of the ventral horn.

It will be well to answer these objections *seriatim*.

(1) It is well known that attacks of poliomyelitis not infrequently pass unobserved in infants. That, however, an attack of poliomyelitis, so severe as partially to paralyse both legs and give rise to a complete paralysis of the shoulder muscles, should occur without giving rise to any constitutional symptom is, I think, most improbable; and, further, we have the direct evidence of the mother that the left arm was paralysed at birth. It seems to me impossible to accept this interpretation.

(2) It is known that the delivery of the child was very rapid, and the child had a fall from the bed at the time of birth. It has been shown by Spencer [5] that hæmorrhage into the spinal cord not infrequently occurs in new-born children. The suggestion, therefore, that the condition might be due to hæmorrhage is one that requires to be carefully considered.

The hæmorrhage, to have caused such widely distributed paralysis, must have been an extensive one, involving both cervical, lumbar, and sacral regions of the cord. Pathologically, there is no evidence that such a hæmorrhage has occurred. Again, when hæmorrhage occurs into the spinal cord it commonly travels along the cord in the region of the root of the dorsal horns, and often leaves a cavity in this region. There is no evidence of such in the present case, and it seems to me most improbable that the spinal condition can be attributed to hæmorrhage taking place within the grey matter of the cord.

(3) That the condition might be due to arrested development in the spinal cord, is I think, a view that could hardly be held. The good development of the major portion of the nervous system, and the scattered nature of the change, quite apart from the character of the changes, make it inconceivable that arrested development can have played a part in the condition.

(4) That the condition was due to an extensive and severe injury to the nerves in some part of their peripheral course, with consecutive atrophy of the cells in the ventral horn.

It is well known that, as the result of damage to peripheral nerves, or amputation of a limb, the cells of the ventral horns undergo certain changes, and may eventually atrophy completely. The condition is one of simple atrophy, and is not attended by changes seen in the white matter of the cord after extensive damage to the grey matter, such as have been shown to be present in this case.

From the clinical point of view, it is again difficult to accept such an interpretation, for the condition of the paralysed arm did not resemble that seen after a birth injury to the roots of the brachial plexus, and it also necessitates the assumption that the peripheral nerves of both legs were injured at birth—a condition which rarely occurs apart from severe and prolonged traction.

The absence of any affection of sensation might be added, although much stress could not be placed on this point, for in infants in whom the roots have been damaged it is most difficult to prove that there is any defect to painful stimuli. In the present case, however, had the extensive paralysis been due to a lesion of the peripheral nerves, it is almost impossible to believe that no sensory and no trophic loss would have resulted.

Although I am aware that the chain of evidence in this case is not complete, yet I think it may with good reason be accepted as one of poliomyelitis occurring during intra-uterine life.

Clinical and Pathological Examination of Case 2.

The second case is that of a female child, aged 2, who was admitted to the Children's Hospital under the care of Mr. F. J. Stewart with a history of hip trouble, which was said to have been congenital. On inquiry, however, it was found that the mother had not had charge of the child for a considerable time, and that the child had been in the infirmary.

On examination, the right leg was flexed, abducted and rotated out, and the head of the femur was so prominent that the condition was thought to be an anterior dislocation.

I saw the child, and, from the extremely flaccid condition of the muscles about the hip-joint and the very marked loss of power, came to the conclusion that the condition was probably one of late poliomyelitis.

The child was very ill at the time with broncho-pneumonia, following measles, and died a few days later, so that a complete and accurate examination of the muscular condition was never made.

The *post-mortem* was made and the spinal cord hardened. On examination of the spinal roots in the lumbar and sacral regions, the dorsal roots appeared of normal size and equal on the two sides.

The ventral roots, however, showed a very marked difference between the two sides, this difference being most marked in the third lumbar root.

On section through the spinal cord, it was noticeable that the right side of the cord was considerably smaller than the left. The ventral horn on the right was much smaller than the left, and the nerve-cells in this region were very few in number. There was an area in the right horn in which the medullated fibres were very much diminished, and this is seen in the photograph as a pale, unstained area (fig. 5).

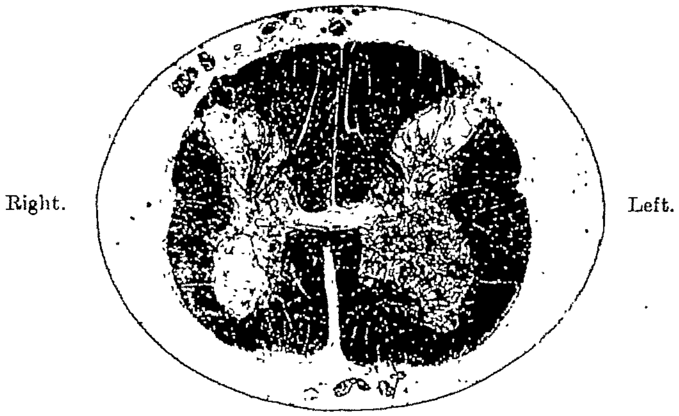

FIG. 5.

Section of cord at level of second lumbar segment (stained by the Weigert-Pal method). The right side of the cord is seen to be considerably smaller than the left, and the grey matter on that side is smaller and shows an area in which there is almost a complete absence of medullated fibres.

There is no doubt as to the nature of the case, but it may well be questioned whether the history of the case can be relied upon.

CONCLUSIONS.

(1) The cases recorded are clinically typical cases of the late results of acute poliomyelitis.

(2) The pathological condition found is that which is commonly found in late cases of poliomyelitis.

(3) In the first case the clinical history is so definite, and the child had been so long under observation, that there is but little reason for not accepting the history as correct and regarding the case as one of intra-uterine poliomyelitis.

In the second case it is fully realized that the clinical evidence is defective, and it is possible that the onset of the acute attack of poliomyelitis occurred after birth.

Finally, although the evidence brought forward is strongly in favour of the assumption that poliomyelitis does occur during intra-uterine life, yet it is fully realized that the chain of evidence is in some respects incomplete.

Having regard to the recent work of Flexner and Lewis [2], Landsteiner and Levaditi [4], and others, as to the infective nature of poliomyelitis, some test other than a pathological one may in future be applicable to these cases, and it will be possible to say, from a clinical examination of the blood, whether the child has or has not had poliomyelitis.

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SYPHILIS OF THE NERVOUS SYSTEM.

Syphilis und Nervensystem. Von Professor NONNE. Berlin: Karger, 1909.

Syphilis of the Nervous System, by F. W. MOTT, F.R.S., being vol. 4 of *A System of Syphilis.* Oxford Medical Publications, 1910.

PUTTING aside for the moment the parasyphilitic diseases, tabes dorsalis, and general paralysis, it is now generally recognized that the older view, enunciated by Fournier in his first edition, that syphilitic nervous disease seldom occurs in the first or second year after infection, is erroneous. Since the publication of Rumpf's [20] and Naunyn's [15] statistics, we know that syphilitic nervous disease is especially frequent within the first year, and, indeed, not rarely within the first month after infection. Naunyn, from the analysis of 335 cases, came to the conclusion that syphilitic lesions of the nervous system were most frequent in the first year after infection, and that 48 per cent. of all such cases occur in the first three years, and that their frequency gradually declines after that time. Gilles de la Tourette [6] has described an unusual and widespread case of severe syphilitic disease of the cerebral and spinal membranes, commencing two months after infection; and Head [8] refers to a case of a man who suffered from continuous headache from the first development of the chancre, the first definite signs of cerebrospinal syphilis developing after three months. The present writer [7] has seen an acute syphilitic paraplegia develop in a man three months after infection, while undergoing a course of mercurial treatment. In one of Nonne's cases severe basal meningitis, with cranial nerve paralysis and acute mania, developed four months after the infection during the course of the secondary rash. After the tenth year cerebral syphilis is exceptional, though there is no limit to its possible appearance; thus, Nonne saw a case with gummatous cerebral syphilis thirty years after infection, and Bruns [2] describes a case in which a large cerebral gumma grew forty years after the primary disease had been acquired. In Sigmund Kohn's [10] case the interval was also forty years.

Nonne's experience agrees with the statement that has been made that syphilis acquired in later life is more liable to strike the nervous system, and he finds that many of his patients who acquired syphilis between fifty and sixty became tabetic after some years. Syphilis in the aged generally runs a more severe course. Of late the question has been much discussed whether there is a special variety of syphilitic poison which is more liable to strike the nervous system, an affinity which may be compared with that of lead for the motor nerves and of ergot for the posterior columns. Numbers of instances of conjugal tabes and general paralysis of the insane in husband and wife have been recorded, which is suggestive evidence on this point. Mendel [13] described a case of a man who infected his wife with syphilis. The man died with general paralysis, and the woman married again and infected her second husband, both of them later developing tabes. Régis [18] published a case of a man who infected his wife and also her sister, all three of them subsequently developing general paralysis. More striking are those instances of a family type, in which tabes, general paralysis, and other syphilitic nerve diseases affect one or both parents, and one or more of their children. Thus in Remak's [19] case the mother developed cerebral syphilis, and her child juvenile tabes. In Nolan's [16] case the father had cerebral syphilis, and the child developed general paralysis. Such cases have been accounted for by the theory that the same heredity and similar surroundings are responsible for the selective action of the syphilitic poison on the nervous system, rather than that there is a special syphilitic neuro-toxin. Nonne gives reasons for disbelieving that the *milieu* is specially concerned in the development of familial syphilitic nervous disease, and he is of opinion that his own experience and also the literature prove that heredity and personal disposition also play no important part in its production. Some remarkable instances have been recorded in which several individuals infected from the same source at the same time have all later developed para-syphilitic nervous disease. Nonne narrates the case of three friends who were all infected in one night by the same woman; one became tabetic, and the other two developed general paralysis. Brosius [1] mentions seven glass-blowers who all developed chancre of the lip, being infected from the blowpipe. Five of these he was able to trace ten years later, and two were tabetic and two had general paralysis. Erb in 1904 related the case of five men all infected from the same source, and all became either tabetic or paretic. Lavallé also gives particulars of five men infected with syphilis at intervals from the same woman; three of them died later of general paralysis, one of syphilitic meningitis, and the other of syphilitic dementia. Another instance recorded is of a man who acquired syphilis from his first wife, and he infected his second wife. Both the women died of general paralysis, but the man escaped. Hübner and others dispute the view of a special syphilitic neuro-toxin, but such facts as those related are strikingly suggestive, though not sufficient perhaps in themselves to establish the theory.

Two points of considerable importance which have been actively discussed are whether cerebrospinal syphilis, tabes, and general paralysis are less likely, or more likely, to follow slight or severe syphilitic infections, and whether the degree of thoroughness with which the syphilis was treated by mercury has any bearing on the after-development of these diseases. Rumpf [20] and others have pointed out that vascular syphilitic disease of the nervous system is due to an insufficient course of treatment for the primary infection, and Erb long ago declared that tabes occurred after slight infections in which no later symptoms arose, and in persons insufficiently treated. In 1903 Marie and Babinski confirmed this view. Neisser showed that of 445 cases of tabes, 57 per cent. had had no treatment for syphilis. On the other hand, Collins, in an analysis of his ninety-six cases, shows that energetic antisyphilitic treatment soon after infection does not prevent parasyphilitic disease of the nervous system developing later. Orlowski [17] came to the same conclusion, as, of seventy-two cases, in sixty-seven antisyphilitic treatment had been carried out, in twenty-three of them very thoroughly. Leyden and Herxheimer, and also Mauriac, go so far as to say that, as regards the development of later nervous symptoms, it is of no account whether the initial syphilis has been treated in the first or second stages thoroughly, or even not at all. Schuster [21] describes thirty-five cases of general paralysis—previously syphilitic—of whom twenty-one had been through one "cure," five had had two "cures," and six had been through from three to nine "cures." He also describes seventy-six patients with cerebrospinal syphilis who acknowledged antecedent syphilis, and twenty-four more who had been through from three to nine "cures" each. He finds no difference in the symptoms of those treated and those who never had antisyphilitic treatment, and the average period of incubation in the treated and in the untreated is much the same. He, too, comes to the conclusion that the idea is false or unproved that mercurial treatment stops or delays the onset of syphilitic or parasyphilitic disease of the nervous system. Nonne also recognized five years ago that in many cases of syphilitic or parasyphilitic nervous disease the mercurial treatment had been most thoroughly carried out; and in two cases, when the nervous complications occurred within the first two years, the treatment had been carried on uninterruptedly from the beginning. As a contrast to these he quotes the case of an officer who became infected with syphilis, but had no treatment for the disease; four months later he developed severe brain-syphilis, which proved fatal. Some good observers are of opinion that brain-syphilis is especially apt to follow the slighter syphilitic infections, but this view does not accord with Nonne's experience. Mott agrees with Nonne, Fournier, and others, that there can be no question of the beneficial effect of early treatment of the primary disease, and that nervous affections are more likely to occur when mercurial treatment has been either insufficient or not practised at all. The point may therefore be still considered unsettled whether early treatment is beneficial or is of no influence in averting subsequent nervous syphilis, but, on the whole, the balance of evidence probably lies in favour of those who advocate the earliest and most systematic course of cure for the primary disease. The conflicting views may perhaps be accounted for by the fact that, as Mott observes, once the *Spirochæte pallida* has gained access to the subarachnoid space and has infected the central nervous system, it is most difficult, if not impossible, to dislodge. In many cases this infection of the nervous system takes place quite early, within the first weeks after the acquirement of the chancre, and thus cerebrospinal syphilis, or later metasyphilitic disease of the nervous system, may follow in spite of the most prolonged and thorough course of mercurial cures. Yet, in those cases in which this infection of the central nervous system with the spirochætes has not as yet taken place, energetic mercurial treatment may be fortunate enough to produce a complete cure and prevent the subsequent development of syphilitic nervous disease. A somewhat similar argument has been put forward in the case of diphtheria, that since the introduction of antitoxin the number of cases of diphtheritic paralysis is greater, and therefore due directly to the use of the antitoxin. The explanation of this seeming paradox lies in the fact that many of the severe cases which formerly would have died are now saved by the use of the antitoxin, and later development of neuritis is due to the severity of the diphtheritic infection and not to the use of the antitoxin.

With regard to the development of the parasyphilitic diseases, tabes and general paralysis, the idea is held by some that not only are mercurial inunctions and other forms of antisyphilitic treatment useless for the cure of these diseases, but that, being neuronal degenerations, the mercury does actual harm by lowering the degree of vital resistance of the tissues, hence hastening the process of neuronal decay. In favour of this view are the observations, familiar to the practice of most physicians, of the startlingly rapid increase in the delusions and mental excitement of an early case of general paralysis, perhaps classed as doubtful, during the course of an energetic administration of mercurial inunction; or, again, a pronounced intensification of the lightning pains and other symptoms of tabes in a patient with the early signs of this disease when similarly treated. On the other hand, many excellent clinicians are firmly convinced that they have seen many cases of undoubted tabes, if not of general paralysis, who have remained apparently permanently improved after the administration of long courses of mercury and iodide of potassium, which such patients sometimes appear to be able to absorb for longer periods without showing symptoms of mercurialism than the average patient. It is difficult to convince such observers that they have been mistaken in their diagnosis, and that these cases which have been benefited by antisyphilitic treatment were not really cases of tabes or general paralysis, but syphilitic pseudo-tabes and pseudo-paresis.

One view [Mott] of the etiology of the parasyphilitic diseases, tabes and general paralysis, which must be mentioned is based on Ehrlich's theory of the artificial production of immunity against disease. It is supposed that there is an inherent aptitude for the cells of the body of certain individuals to adapt themselves readily for defence against the action of the syphilitic virus in a race that has been widely syphilized for generations; consequently a larger number will have a mild form of the disease. The nerve cells are perpetual elements incapable of regeneration, highly differentiated and complex in structure and function; their centre of nutrition is the nucleus, and when decay sets in the retrogressive process attacks first the fine twigs and branches and rootlets of the tree, the dendrites and dendrons; in fact the process is an inversion of its growth and development. We know the prolonged duration of infectivity of the syphilitic virus as compared with other contagious diseases, also that one attack of syphilis as a rule confers immunity during the rest of the individual's life. Hence, the nerve-elements being perpetual, and having acquired a habit of throwing off side-chain molecules, will continue to do so during life, and will contribute largely to the immunity produced. When there is no longer metabolic equilibrium and decay of the neuron sets in, these antibodies are thrown off in increasing numbers, as shown by the presence of serum albumin in the cerebrospinal fluid, and the positive reaction of this fluid to the Wassermann test for syphilis, although in cerebrospinal syphilis this fluid gives a negative reaction when the blood serum is positive to the test. That the antibodies are thrown off in increasing numbers seems probable from the fact that in general paralysis and tabes the quantities found in the cerebrospinal fluid increase with the progress of the decay; for Marie and Levaditi [12] have shown that there is a parallelism between the rapidity of progress of general paralysis and the degree of intensity of the Wassermann reaction. No doubt, therefore, there is a connexion between the breaking down of nervous substances (destructive metabolism) and the amount of this complex colloidal substance, with which probably the reaction is associated and upon which it depends.

The spinal cord is much less frequently affected by syphilitic disease than is the brain, in the proportion of one spinal case to eight or ten cerebral. Spinal syphilis is much less serious, on the whole, than brain syphilis, though in the majority of fatal cases of syphilis of the nervous system both brain and spinal cord have been found affected. It is, in fact, a constant anatomical finding that the syphilitic lesions of meninges, vessels, and cord are invariably much more widespread than the symptoms would lead one to suppose; and though the symptoms may be entirely spinal, and apparently focal, widespread lesions are likely to be found, involving the brain in addition to the spinal cord. Thus Siemerling showed that extensive syphilitic changes in the brain can remain latent during life, and also that spinal changes may be latent in apparently pure cerebral syphilis. In Weygandt's case, clinically one of pure cerebral syphilis, widespread vascular changes in the cord down to the lumbar region were found post-mortem. In Nonne's case of apparently pure severe transverse lumbar myelitis he found post-mortem, in addition to a gummatous meningo-myelitis, an extensive gummatous infiltration at the base of the pons, and in the interpeduncular space. Cerebrospinal syphilis, like primary syphilis, is much more frequent in men than in women. The influence of a neuropathic disposition in the etiology of spinal syphilis is not known, but spinal trauma and functional overstrain have been definitely shown to be exciting factors in its development. Thus, a sailor, ten years syphilitic, received severe blows on his back during a storm. Six months later the first symptoms of meningo-myelitis appeared, which did not react to treatment with mercury and iodide. After five years' illness he died, and post-mortem widespread meningo-myelitis, with severe vascular changes, was found. The present writer has seen a similar clinical result follow a slight spinal injury: a man, aged 26, jarred his back by a fall from a sofa; immediately afterwards he noticed a numb feeling in the lower part of his back, and this numbness, varied by occasional pains, has troubled him ever since. Six months later he developed pains round the lower ribs and in the legs, and two and three-quarter years later he developed internal ophthalmoplegia, first in one eye and later in the other. A year later the pains in the back and legs increased, and weakness of the legs appeared, with all the symptoms of an organic spastic paraplegia, which cleared up almost completely after thirteen weeks of mercurial treatment. Though he denied all venereal disease, the Wassermann test was positive. It is easy, however, to overstate the effect of trauma in producing cerebrospinal syphilis, and Nonne, in a large experience, saw only two cases in which cerebral syphilis definitely followed, in one case two weeks and in the other three months, after a severe blow on the head. A case of Fournier's illustrates the effect of overstrain of the spinal functions. A man took a long and severe bicycle ride, and almost immediately after developed pains in the back, bladder-weakness, progressive paraplegia, and died of a characteristic syphilitic myelitis. The question whether cerebrospinal syphilis and the meta-syphilitic diseases, tabes and general paralysis, may be actually developed as the result of injury to spine or head in a syphilitic subject is a point of considerable medico-legal importance, and the question as to whether the symptoms would not have developed in any case is one almost impossible to decide definitely. Mott points out the well-known fact that traumatic neurasthenia is frequently seen as the result of injuries to head or spine, and he argues that in a syphilitic subject such a nervous system is a *locus minoris resistentiæ*, and that general paralysis may develop as the sequel of such a condition when it would never have appeared without the antecedent injury.

Nonne classes syphilitic lesions of the nervous system under three headings: (1) Gummatous new growths; (2) Chronic hyperplastic inflammations; (3) Vascular disease. Gummata of the dura or of the spinal cord alone are rare, though more frequent in the brain. By far the most frequent lesion is a diffuse meningo-myelitis, in which the gummatous hyperplastic inflammation invades the leptomeninges, spinal cord and roots, with widespread vascular disease, affecting both arteries and veins alike with endo- and peri-arteritis, and endo- and peri-phlebitis.

As a result of thrombosis or occlusion of vessels, patches of softening with hæmorrhage may occur in the grey as well as the white matter. The picture of acute myelitis may thus be produced, which we should not be justified in ascribing to syphilis, unless there were a history or signs of syphilitic disease, and a condition of the vessels as has been described. When the grey matter is affected an acute poliomyelitis may occur, followed by atrophic muscular paralysis. Spiller describes such a case affecting all four limbs, due to syphilitic thrombosis of the anterior median spinal artery. Subacute poliomyelitis may also occur, affecting generally the upper extremities. Mott explains the frequency of syphilitic transverse myelitis in the mid-dorsal region by the particularly poor blood supply of this region of the cord, and he also suggests that the chronic venous congestion and peri-arterial inflammation which occurs in an acute gummatous meningitis would leave behind a slow sclerosing fibrosis most intense, and most likely to result in a chronic fibrous infiltration along the pial septa enclosing the nutrient vessels of the cord substance. He would thus explain the pathology of Erb's syphilitic spinal paralysis, this theory avoiding the necessity of assuming a primary degenerative process affecting the pyramidal system below the dorsal region.

Although there are not wanting authorities in the French school, Nageotte, Leredde, &c., who assert that tabes and general paralysis are secondary nerve degenerations following a chronic syphilitic radicular neuritis and meningitis, yet it is generally assumed that these degenerations are primary and parasyphilitic, not dependent upon any true syphilitic process, and therefore not curable by antisyphilitic remedies. Mott and others declare that so-called cures of tabes and general paralysis by mercurial inunction were not really cases of tabes and general paralysis, but instances of pseudo-tabes and pseudo-paresis, due to a chronic diffuse meningeal and radicular inflammation of syphilitic origin. Many cases of so-called primary tract degenerations of the pyramidal tracts and postero-lateral columns have been recorded, but many of them are open to the explanation given by Mott of antecedent damage from meningeal inflammation to the nutrient vessels of the cord in the mid-dorsal region. Others may be due, as Gordon Holmes showed in a recent case, to a primary focal softening at a distance, such as symmetrical pyramidal degeneration due to a patch of softening in the pyramidal decussation in the medulla. Optic atrophy, apparently primary, may be similarly traced to an unsuspected focus of gummatous infiltration of the chiasma. Nerve-cell degenerations appear to be sometimes primary, notably the well-known sclerotic degeneration of the third, fourth, and sixth cranial nerve nuclei, known as nuclear palsy.

The examination of the cerebrospinal fluid gives very valuable help in the differential diagnosis of general paralysis from neurasthenia and alcoholism. The presence of a mononuclear lymphocytosis will at once exclude the latter. Lymphocytosis alone is not certain proof of a meningeal reaction, and has been met in herpes zoster, subacute combined sclerosis, &c. In syphilitic meningo-myelitis the cell count in the cerebrospinal fluid will be especially high, much higher than in any case of tabes or general paralysis, though in the latter the lymphocytosis will not diminish under mercurial treatment, while in syphilitic spinal disease the leucocytosis will gradually disappear under treatment. The proteid content of the fluid is notably increased in tabes, and especially general paralysis. In normal cerebrospinal fluid there is a trace of globulin present, but albumin is absent. In parasyphilis the globulin is much increased, and it may be precipitated by saturation with magnesium sulphate, and after filtration further saturation with ammonium sulphate will demonstrate the presence of serum albumin. In addition to this chemical test and the examination of the cell exudate, the examination of the fluid for the Wassermann serum reaction for syphilis will be of great service. Mott declares that in parasyphilis, especially general paralysis, the cerebrospinal fluid will give a positive reaction to the Wassermann test, as well as the blood serum; that is to say, in over 90 per cent. of cases of general paralysis the reaction in the cerebrospinal fluid is positive, while in other syphilitic affections of the nervous system, such as meningo-myelitis, syphilitic arteritis, &c., the cerebrospinal fluid will give a negative reaction to this test, although the reaction in the blood may be positive. Mott quotes a very instructive case in which this point alone decided the diagnosis in a case of general paralysis, in which the clinical symptoms were mainly misleading. According to this teaching, the Wassermann reaction used in association with a lymphocytic count will become all-important in the diagnosis of syphilis and parasyphilis of the nervous system. Thus: (1) A positive reaction in the blood with a negative reaction in the cerebrospinal fluid and no lymphocytosis indicates that though the patient has had syphilis it has not affected his nervous system; (2) A positive reaction in the blood, a negative reaction in the cerebrospinal fluid, and definite lymphocytosis signify that he is suffering from active syphilis of the central nervous system; (3) A positive reaction in the blood with a positive reaction in the cerebrospinal fluid and a lymphocytosis points to a parasyphilitic condition of the central nervous system. If these reactions are found to be trustworthy we shall have gained a most valuable means of diagnosis.

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PUBLICATIONS RECENTLY RECEIVED.

[Notes on a book under this heading do not preclude a subsequent review.]

Epidemic Poliomyelitis. Report of the Collective Investigation Committee on the New York Epidemic of 1907. Pp. 119. New York: Journal of Nervous and Mental Disease Publishing Co., 1910.

During the summer and autumn of 1907, at least 2,500 cases of poliomyelitis occurred in New York and its vicinity. The Neurological Society formed a committee to investigate this epidemic, and this pamphlet contains the results it obtained. The incubation period was from four days to about a week; but in no case did the circumstances permit of its certain determination. No cause was discovered, and the disease attacked mainly young children. Pain was a common symptom, and meningeal affection was frequent, especially in the early stages. As usual, abortive forms occurred sufficiently often to confirm the statements of the Swedish observers. No single case of cerebral affection or infantile hemiplegia occurred during the epidemic. Flexner and Lewis give an account of the means by which they were able to transmit the disease from two human cords to two monkeys, and from them to a series of other monkeys by intracranial injection. They could find no organisms of any kind, and the virus passed through a filter and withstood glycerinization; it is therefore not bacterial in nature.

A System of Syphilis, in Six Volumes: Vol. IV., Syphilis of the Nervous System. By F. W. MOTT, M.D., F.R.S. Pp. 502, with many plates and illustrations in the text. London: Frowde and Hodder and Stoughton, 1910.

This magnificent work is the first comprehensive statement in English of the relation between syphilis and diseases of the nervous system in the light of recent additions to our knowledge. Dr. Mott, in the first five chapters, deals with the general pathology of syphilis of the nervous system, the symptoms of syphilis of the brain and of the spinal cord, and the parasyphilitic diseases. Then follows a valuable chapter on the cerebrospinal fluid, with a full discussion of the diagnostic value of the Wassermann reaction in syphilis and parasyphilis of the nervous system. More than seventy pages are devoted to the etiology of tabes dorsalis and dementia paralytica, and the symptoms of tabes are dealt with consecutively later in the volume. A chapter is devoted to the difficulties of diagnosis and treatment fully considered. Dr. Mott ranks himself definitely amongst those who believe that mercurial treatment is useless or even harmful in parasyphilis. The plates are admirable, but a few of the figures in the text will probably be improved in a second edition. For there is no doubt that this work will become the standard hand-book for English practitioners.

Die Trypanosomenkrankheiten und ihre Beziehungen zu den syphilogenen Nervenkrankheiten. Von Dr. WALTHER SPIELMEYER. Mit 6 Tafeln. S. 106. Jena: Fischer, 1908.

The discovery of the *Spirochæte pallida* has added peculiar interest to all diseases due to invasion of the body by trypanosomes. This work gives the pathological appearances found in sleeping-sickness and in experimental trypanosomiasis. The author concludes that the sum of clinical and anatomical appearances points to a relationship between trypanosomiasis and its consequences and syphilis and parasyphilis. Dourine is normally contracted by the horse during connexion, all trypanosome diseases tend to affect the lymphatic glands, and all tend to produce system-degenerations in the nervous system. The coloured plates are excellent.

Das psychogalvanische Reflexphänomen. Von Dr. OTTO VERAGUTH. Mit 44 Abbildungen. S. 187. Berlin: Karger, 1909.

Dr. Veraguth was the first to use galvanometric changes in the normal skin currents as a test for psycho-physical disturbances. This method was adopted by Jung for registering the disturbances discovered by psycho-analysis, and a paper on the subject appeared in *Brain*, 1907. The inventor of the method has now put together his experiences in a careful monograph dealing with the technique and results he has obtained. There seems to be no doubt that the galvanometer can give undoubted indications of affective disturbances which arise in the course of a psycho-analytical examination. The galvanometer curves run parallel in most cases with the reaction-time records, and evidently are affected by the same emotional factors. The book is written with a commendable absence of the exaggerated claims put forward by some of those who have worked with this method.

Ueber die medizinischen Folgezustände der Katastrophe von Courrières [10 März, 1906]. Von Dr. EDUARD STIERLIN. S. 188. Berlin: Karger, 1909.

The author investigated the condition of the miners saved from the pit after the disaster at Courrières. He watched them in some cases for two and half years, and compares the result of his observations with the conditions he found after the earthquake at Valparaiso and that in the South of Italy. The work is an interesting contribution to our knowledge of traumatic neuroses, on account of the full clinical histories, and careful examination of the sufferers. In some cases of pronounced carbonic-oxide poisoning, a dementia resulted closely resembling that produced by gross organic disease; some cases showed all the signs of a severe traumatic hysteria. Unfortunately, like so many German monographs, this book has no index.

Reports from the Pathological Laboratory of the Lunacy Department [*New South Wales Government*]. Vol. II. Part I. Sydney: The Government of the State of New South Wales, 1910.

This volume contains a paper by Dr. Flashman and Dr. Latham on the pathology of general paralysis, with special reference to the action of diphtheroid organisms, in which they came to the conclusion that "diphtheroid organisms administered in a suitable way over a long period can produce marked cerebral changes, the chief of which are overgrowth of neuroglia, periarteritis, chronic thickening of the pia-arachnoid and destruction of neurones." A paper by Dr. Flashman and Dr. Butler deals with the Wassermann reaction in syphilis and general paralysis; their results confirm those of Mott and other workers. There are also two small papers by Dr. Flashman on degenerations following resection of the optic lobe and portions of the cortex in Dasyurus Viverrinus.

Gehirn und Schädel. Eine topographisch-anatomische Studie in photographischer Darstellung. Von Dr. Fr. HERMANN. Mit 69 zum Teil mehrfarbigen Lichtdrucktafeln. Jena: Fischer, 1908.

This article contains the photographic reproductions of the contents of the cranial cavity, from the moment the skull cap is removed to the last of a series of sections. The first twenty-three plates show sections taken at a slightly inclined horizontal level. Then follow a set of vertical sections from before backwards and from behind forwards, so as to include the relations of the cerebellum. These are followed by a series of sagittal views of various parts of the brain. To every plate is attached an explanatory figure, generally in the form of a transparent cover, upon which the various structures are named that are visible on the photograph. Medical libraries should possess this work, which will be useful to those unfamiliar with the topographical relations of the various regions of the brain to the skull.

Physiology of the Special Senses. By MAJOR GREENWOOD, Junr. Pp. 239. London: Arnold, 1910.

This book is intended as a companion to the "Text-book of Experimental Psychology" by Dr. Myers, and will be useful to those who are working for one of the higher examinations. So much of our knowledge of the physiology of the special senses is recently acquired that it is peculiarly difficult to present the various subjects clearly, and at the same time to refrain from accepting some highly controversial standpoint. But, as far as the space at his disposal permits, Dr. Greenwood has given an excellent critical account of recent work. The senses are considered in order, beginning with those of the skin and subcutaneous structures. More than half the book is occupied with various problems in vision, and a chapter is devoted to each of the two main theories of colour vision. The advice to the student with regard to further study at the end of each chapter is uniformly excellent.

Handbuch der Neurologie. Herausgegeben von M. LEWANDOWSKY. Erster Band—Allgemeine Neurologie, I and II Theil. S. 1606, with 322 figures and 12 plates. Berlin: Springer, 1910.

This valuable work forms the first volume of a System of Neurology. Here the various departments of neurological knowledge are treated at sufficient length to make them useful to the serious worker in the subject. It contains over 1,600 pages, and deals with the histology, the anatomy, and the experimental physiology and pathology of the nervous system. The last part of the book deals fully with the treatment of nervous diseases. The different chapters maintain a remarkably high level, and, although closely packed with information, are unusually readable. If the remaining volumes are as good as the first, this hand-book will be indispensable for every neurologist.

A Text-book of Nervous Diseases. By WILLIAM ALDREN TURNER, M.D., and THOMAS GRAINGER STEWART, M.B. Pp. 607. London: Churchill, 1910.

This text-book is well suited to the needs of the practitioner and senior student. It is clearly and succinctly written, it is thoroughly up to date, and the illustrations are excellent.

Die Indikationen zu chirurgischen Eingriffen bei inneren Erkrankungen. Von Prof. Dr. HERMANN SCHLESINGER. Mit einem Anhange von Prof. Dr. JULIUS SCHNITZLER. S. 614. Jena: Fischer, 1910.

The portion of this volume of interest to neurologists comprises just over 100 pages, devoted to surgical measures adopted in diseases of the nervous system. Owing to the limitations of the work, the differential diagnosis and indications for operation in cases of tumour and abscess of the brain are not given with sufficient fulness to be of much value. Epilepsy, primary and secondary to trauma or local brain disease, is treated in a few detached paragraphs. Laminectomy and operations on the peripheral nervous system are dealt with as if the author had no personal experience of such procedures and was ignorant of the measures usually adopted in this country.

[OCTOBER, 1910.]

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BRAIN.

PART II., 1910.

Original Articles and Clinical Cases.

THE MESENCEPHALIC ROOT OF THE FIFTH NERVE.

BY OTTO MAY, M.D. (BEIT RESEARCH FELLOW),
AND
SIR VICTOR HORSLEY, F.R.S.

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I.—CURRENT VIEWS AS TO AXONES COMPRISING THE *TRACTUS MESENCEPHALICUS QUINTI* BEING AFFERENT OR EFFERENT, OR CENTRIFUGAL OR CENTRIPETAL.

THE origin and distribution of the mesencephalic root of the fifth nerve were very variously described until the last decade, during which a great deal of work by numerous observers was accumulated, consisting almost entirely of investigations on the structure and destination of the axones of the large globular cells which are scattered along this root.[1] The most generally accepted description of the characteristic cells and their large axones is that given by Kölliker [21] and Ramon y Cajal [27]—namely, that the axones of the cells consist of a thick limb and of a fine collateral, or slender limb. Of these, the former descends as far as the motor nucleus of the fifth nerve, and there gives off collaterals which ramify around the cells of that nucleus. After passing this nucleus, the axones were followed by Boyce [3], van Gehuchten [33], Kölliker, &c., as far as the exit of the fifth nerve from the pons. No observer, however, has attempted to discover the destination of these fibres by tracing their course when degenerated after their division in the mesencephalon. It was the object of the present communication to answer this question as far as possible, and the material collected has also furnished the opportunity of clearing up various points concerning the central relations of the fifth nerve.

Probst (*vide infra*) described a continuation of these axones in the dorsum of the bulb, sending collaterals to Deiter's nucleus, and ending in the nuclei of the vagus and glossopharyngeal and the fasciculus solitarius. These fibres do not arise, however, from the fifth nerve (*vide infra*).

An attempt was made by Terterjanz [31] to support certain theoretical views of Kölliker on the peripheral distribution of the mesencephalic trigeminal fibres. To this end he removed the palatal muscles in a few animals, and described retrograde degeneration, as evidenced by Marchi's method, in the mesencephalic root of the fifth nerve. Examination of his drawings, however, does not, in our opinion, confirm the conclusions he founded upon them.

With respect to the fine collateral, or slender limb, of the axone of the mesencephalic cells mentioned above, no investigations of its distribution have been made, beyond the description given by Ramon y Cajal [28]. This is clearly a point for further consideration, and reference to it is made below.

A different question has now to be considered with regard to the mesencephalic root—namely, whether it has any afferent function in addition to the efferent or motor one just described. The view that it is essentially a sensory mechanism has recently been revived by

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[1] Morphologically no confusion is now possible between the globular trigeminal nerve cells, which, as Obersteiner showed, are of common type in all animals, and the tectal cells lying among them and forming the nucleus intertrigeminalis of Kohnstamm. (See fig. 1.)

Johnston [15] on the basis of the study of fibre-stained serial sections of normal brains, adult and embryonic. From these he deduced the opinion that the mesencephalic fibres, after passing the motor nucleus of the fifth, entered its sensory root. He therefore regards the whole tract as an afferent mechanism. We reserve to the end of our paper the final discussion of this important question. His view, which relates only to centrifugal axones, the function of which is still indeterminate, would have gained strength had he employed the Marchi method and recognized that the root contains both centrifugal and centripetal fibres. Of the afferent character of the latter there can be no doubt.

We think it best to present the results of our work according as they illustrate the course and relation of centrifugal and centripetal axones respectively. We have investigated these both by chromatolysis and by Marchi staining of sheath degenerations.

At the same time, inasmuch as a great deal of our material throws light on the course taken by the centripetal fibres of the fifth nerve other than those running in the mesencephalic root, we add the discussion of this part of the subject also.

(II)—EXAMINATION OF CENTRIFUGAL AXONES IN THE MESENCEPHALIC ROOT.

(a) By Chromatolysis.

We have endeavoured to investigate the destination of the fibres of the mesencephalic tract by an examination of the chromatolysis resulting from lesions at different points in the course of the fifth nerve. The lesions were:—

(α) Division of the mesencephalic root intracerebrally at different points: (1) opposite the interval between the colliculi, (2) opposite the middle of the posterior colliculus, or (3) close behind the posterior colliculus, and just ventral to the fourth nerve.

(β) Division of fifth-nerve roots between exit from the pons and the Gasserian ganglion.

(γ) Division of the first and second parts of the fifth nerve, distally to the Gasserian ganglion.

(δ) Division of third part of the fifth nerve distally to the Gasserian ganglion, (1) at foramen ovale, (2) by avulsion of the branches more peripherally.

Methods Employed.

For this work cats and monkeys were employed. The procedure was the same throughout. The operation of division of the mesencephalon, or of the nerves, was performed under chloroform or ether anæsthesia, and with strict antiseptic precautions. The animals were kept alive for the usual period of two to three weeks, then, after being tested physiologically, they were killed under an anæsthetic, and the arterial system perfused with 10-per-cent. solution of formalin in normal saline. The central nervous system was then removed to a similar solution, in which it was allowed to remain for twenty-four hours. The tissues were then treated in the usual way, cut in paraffin, and stained either by Unna's polychrome blue or by Pappenheim's pyronin method.

Results.

(α) *Lesions of the mesencephalic tract,* anterior or cephalad to the motor nucleus of the fifth.

The results obtained were very striking. The chromatolytic changes that occurred on section of the mesencephalic root were rapid in development and extreme in degree. In all the animals examined (four), the characteristic mesencephalic cells above the lesion had, for the most part, entirely disappeared. This notable result may best be accounted for by our view that the tract contains both afferent and efferent fibres. It is possible also that the effect of the intracerebral section is exaggerated by concurrent interference with the circulation. That the latter is, however, a very limited factor is shown by the fact that in several cases the incision was an extremely small puncture, unaccompanied by any obvious consequent thrombosis (*cf.* Kohnstamm [20]) on reactive atrophy.

(β) *Section of the roots of the fifth nerve between the pons varolii and the Gasserian ganglion.*

This operation of division of the roots of the fifth nerve between the Gasserian ganglion and the pons was performed in four animals—three cats and one monkey (*Macacus rhesus*). It was followed in every case by extensive chromatolysis of the characteristic globular trigeminal cells as previously described by Kure [30]. This particular operation furnished also the answer to an important question, which can suitably be disposed of at this point—namely, the true relation of the cells of the locus cæruleus to the fifth-nerve tracts. This includes another question, whether the multipolar cells of the locus cæruleus are in any way part of the trigeminal system. Kohnstamm and Quensel [18] regard them as being part of a nuclear system, in relation with the globular cells and the coarse axones of the mesencephalic root. Evidence for this view, however, is not obtained from our experimental material.

Personally, we have seen nothing to suggest that these cells undergo change either of a direct kind, when the afferent trigeminal channels are interrupted, or of a retrograde type, when the mesencephalic trunk has been divided at a sufficient distance from the locus cæruleus to avoid actual involvement of it in the injury.

Further, the photograph (fig. 12) of a section through the locus in a patient in whom the Gasserian ganglion had been removed six weeks before demonstrates that the cells of the ipsilateral nucleus are unaffected.

Our conclusion, therefore, is in confirmation of that of Cajal, that these cells constitute a separate ascending system, which is not connected, at least directly, with the fifth nerve.

(γ) *Section of divisions of the trigeminal nerve, distal to the ganglion.*

In the monkey (*Macacus rhesus*) it was found that section of the superior and middle divisions of the trigeminal nerve, just peripheral to the Gasserian ganglion, produced no signs of chromatolysis in the globular cells of the mesencephalic root or in those of the locus cæruleus. The completeness of the lesion was confirmed by the presence of total degeneration of the branches of these two divisions, as shown by Marchi staining. It seems reasonable to conclude, therefore, that the centrifugal axones of the mesencephalic root are not continued into either of these divisions of the nerve.

(δ) Very different are the results of *section of the inferior division*, or avulsion of its branches. Intracranial section of this division at the foramen ovale was performed on three animals (one cat and two monkeys). Extracranial avulsion of its branches in the spheno-maxillary fossa was done in four cats, while in one the motor branches were removed, leaving the sensory part intact. In all these animals chromatolytic changes were observed in many of the characteristic mesencephalic root cells throughout the entire length of the root. The typical changes (see figs. 1 and 2) were exhibited—namely, the extrusion of the nucleus to one side and the fusion of the chromatin granules—but what was especially striking was the fact that, even in so short a time as twenty-one days, some of the cells had shrunk to mere remnants or had almost entirely disappeared.

In the animal (cat) in which the motor branches were destroyed without injury to the sensory branches, the chromatolysis was also

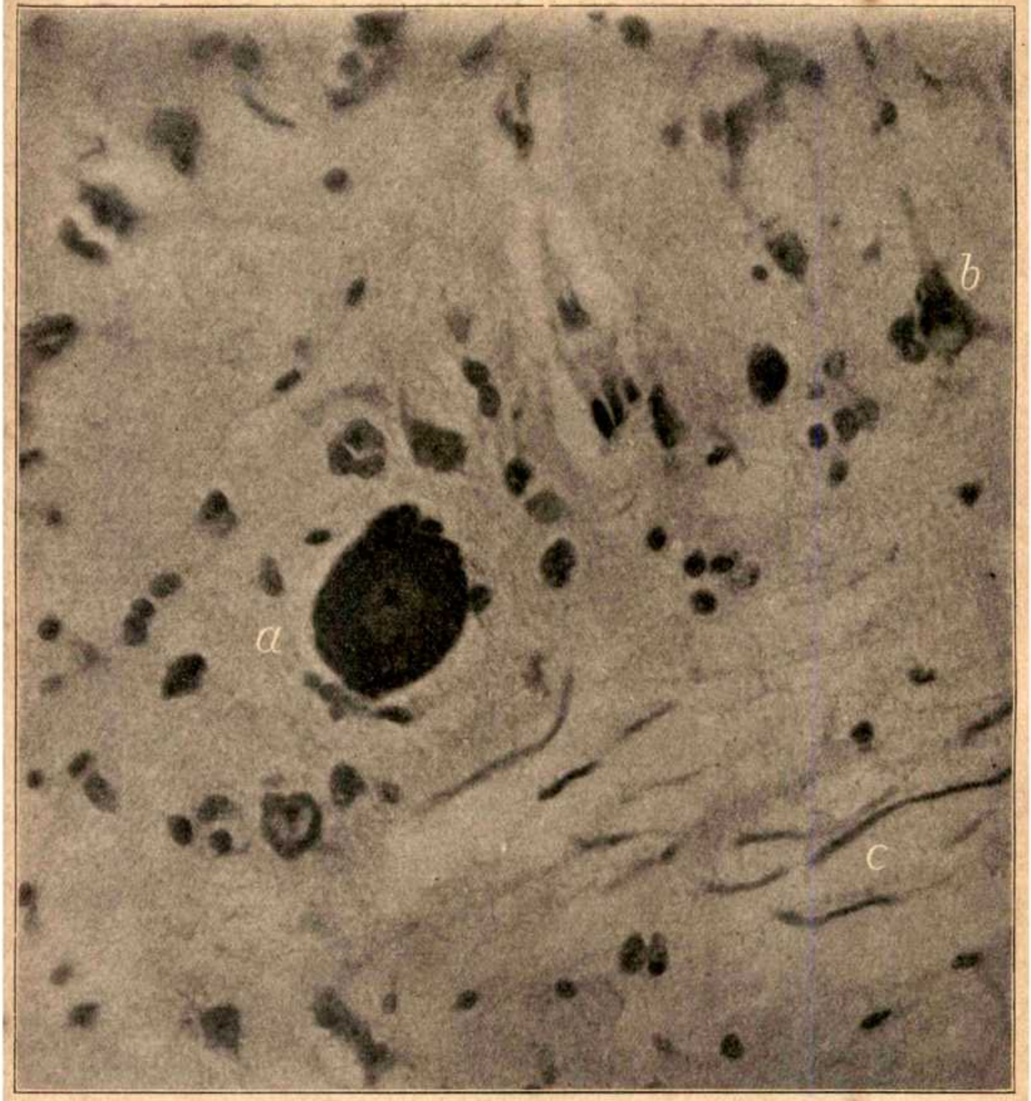

FIG. 1.

Macacus rhesus—Normal. Tractus mesencephalicus quinti—showing typical globular nerve corpuscles (*a*) of the tract, as well as axones; also a cell of the nucleus intratrigeminalis (*b*) of Kohnstamm, and axones of the tractus (*c*).

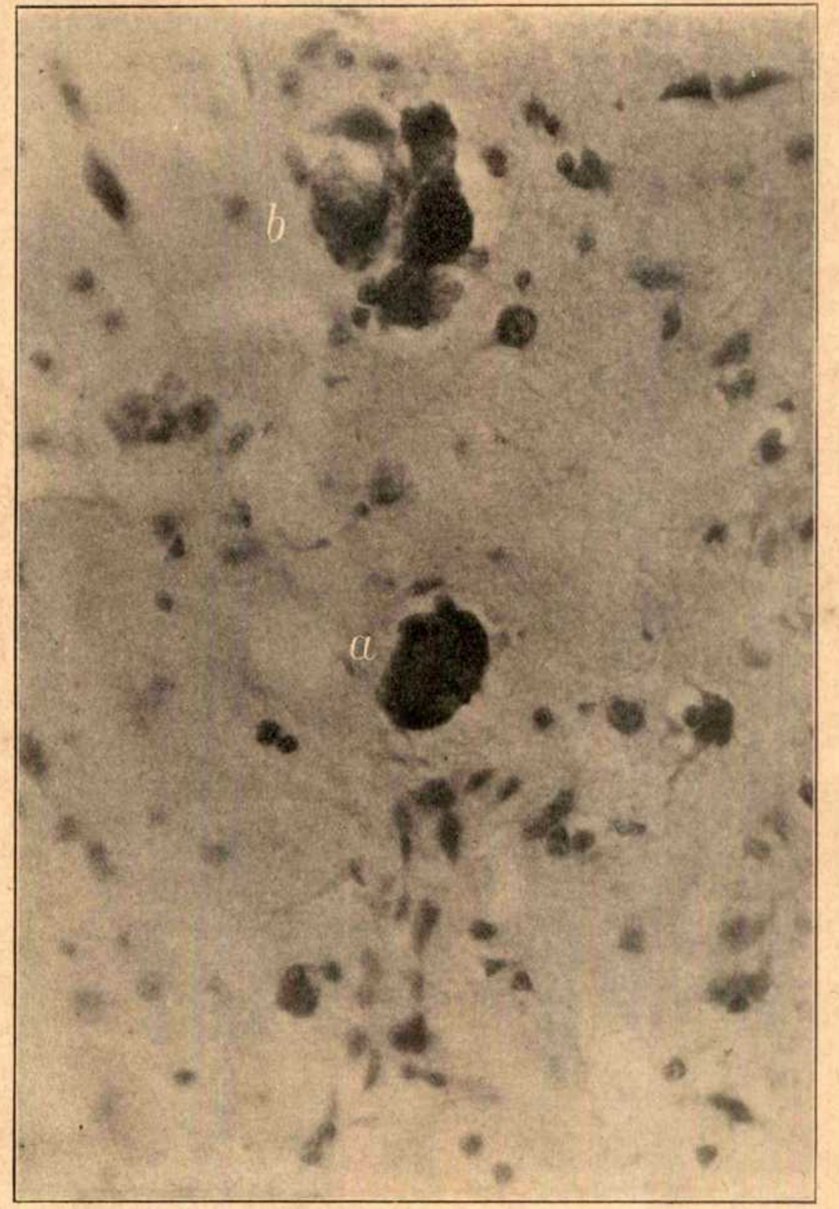

FIG. 2.

Macacus rhesus.—Chromatolysis of the globular cells of the tractus mesencephalicus quinti after avulsion of the inferior division of the fifth nerve. The solitary cell (*a*) shows shrinkage, lateral position of the nucleus. The group of cells shows (*b*) complete destruction of the cells and disappearance of the nuclei.

present. This observation does not lend support to Johnston's view that the axones enter the sensory root.

Just as in the division of the nerve proximal to the ganglion, so in these experiments of division distally to it there was no change in the cells of the locus cæruleus, although the cells in the mesencephalic root showed marked alteration.

Finally, these series of experiments showed particularly clearly the truth of the principle enunciated by Gudden and Forel and others, that the degree of chromatolysis depends upon the site of the injury. Thus the degree and rapidity of the destruction of the nerve cells increases as we proceed with the experimental sections in the following order :—

(*a*) Section of peripheral branches distal to the root ganglion.

(*b*) Section of the roots of the trigeminus between the root ganglion and the pons varolii.

(*c*) Section of the trigeminal roots in the pons varolii.

(*d*) Section of the tractus mesencephalicus trigemini in the plane of the posterior colliculus.

The last-named lesion caused, as stated above, total disappearance of the nerve cells in a very short time.

(*b*) *By Degeneration of Centrifugal Axones of the Mesencephalic Root following its Intra-cerebral Division.*

Operative Procedure.

To produce centrifugal degeneration in the mesencephalic root alone we divided it by exposing the mesencephalon at the level of the anterior border of the tentorium, and then making a small puncture incision—(*a*) through the side of the posterior colliculus,[1] or (*b*) just in front of it, or (*c*) just behind it where the fourth nerve passes out. We thus obtained section of the mesencephalic root at three points in its course, the lowest of which was at a considerable distance above the motor or masticatory nucleus.

We hoped by these measures to determine completely the ultimate destination of the mesencephalic root axones. To this end we employed the Marchi method. The Gasserian ganglion and the peripheral branches of the nerve were also stained by the same method, the latter being first dissected out and separately identified. After staining, these nerves were examined for degenerated fibres by teasing. The ganglia were cut in serial section for the same purpose.

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[1] Corpus quadrigeminum posterius.

In our first series of experiments the results seemed so contrary to expectation that we thought there must be some underlying error of observation. Accordingly we extended the number of experiment until on this point our series included twenty monkeys and ten cats.

Results Obtained.

In the first place, the amount of degeneration of the centrifugal axones is exactly proportional to the number of cells above the site of the lesion. This is the converse proof of the statement already made in respect of the chromatolytic results which follow intracerebral division of the mesencephalic root (*vide* p. 179)—namely, total destruction and disappearance of the globular cells situated above the lesion.

In the second place, the course taken by these axones is that described by Boyce, Cajal, and others—namely, curving round the outer side of the motor nucleus, sending collaterals thereto, and passing on, to make their exit from the pons between the sensory and motor roots (see figs. 3 and 4). As the accompanying photograph shows, these fibres in the monkey (*Macacus rhesus*) traverse the sensory root in part, but ultimately approach the motor root. Comparison of our photographs with the figures drawn by Johnston [15] of the path of these fibres in the human embryo shows that the path taken by the axones is the same in different species of the Primates; but, in contradistinction to the conclusions arrived at by him, we consider that their ultimate relation is with the motor and not the sensory root (see fig. 4). On this question the degeneration method affords irrefragable evidence.

We have now to consider three points in connexion with the axones during their course through the side of the pons : (1) in the first place, the question of axones, or principal collaterals from them, passing down into the bulb, as described by Probst ; (2) in the second the number and degree of collateral supply to the motor nucleus ; and (3) in the third, the continuation of the axones from the pons.

(1) The statement made by Probst [27] that some of these axones run caudally, sending collaterals to Deiter's nucleus, and terminating in the nuclei of the vagus and glosso-pharyngeal, and the fasciculus solitarius, is, in our opinion, not borne out by the facts, when the lesion is limited to a simple division of the mesencephalic root. In his experiments, the lesion made with a hook and cannula was extensive, and

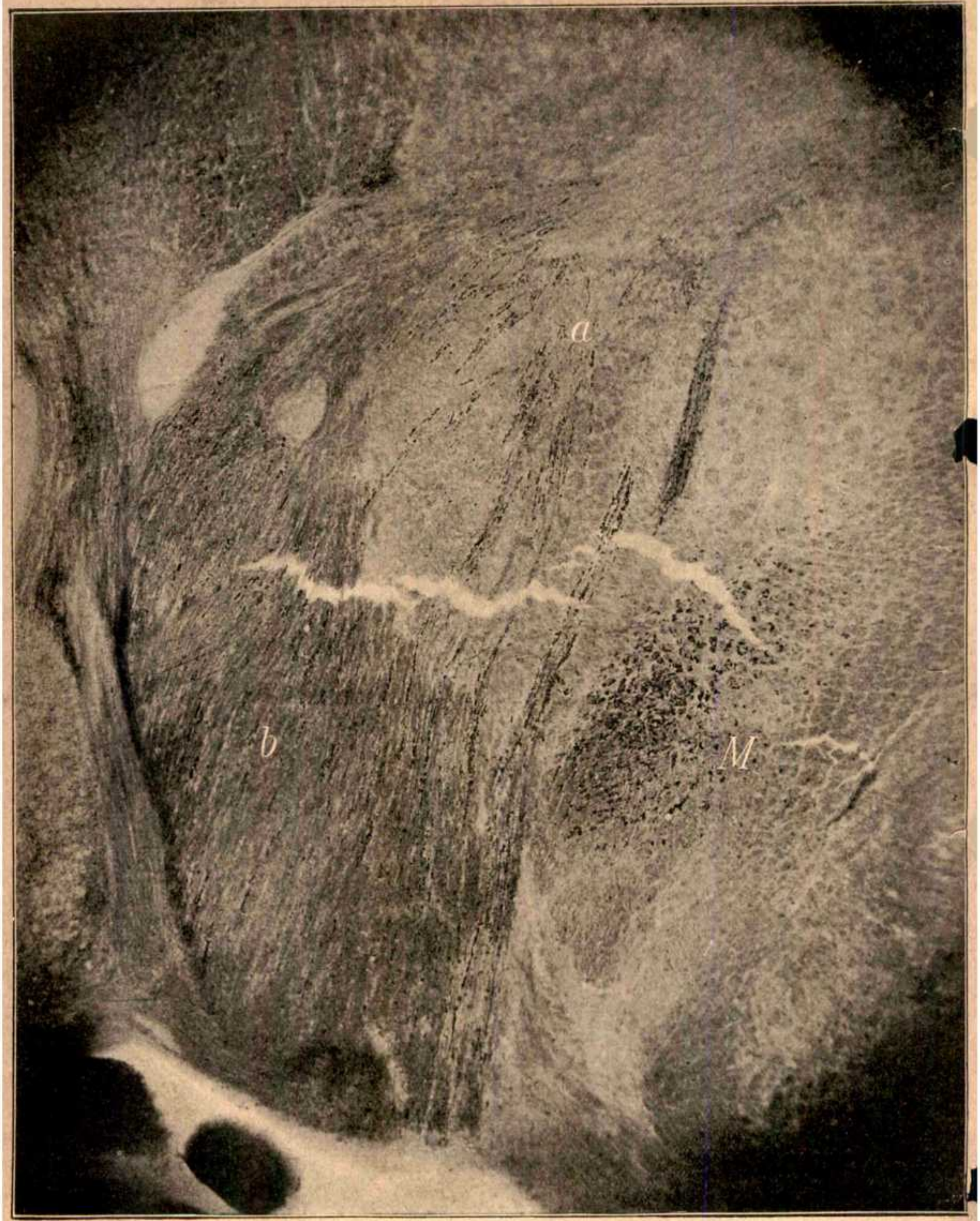

Fig. 3.

Cat—Section.—Showing how the fibres of the tractus mesencephalicus (*a*) pass outwards through and among the fibres of the sensory root (*b*) (but gain ultimately the motor root).

In the experiment, which was one of a mesencephalic lesion, Monakow's rubrospinal tract was injured, and is shown (*m*) degenerated in transverse section, just to the inner side of the fifth nerve.

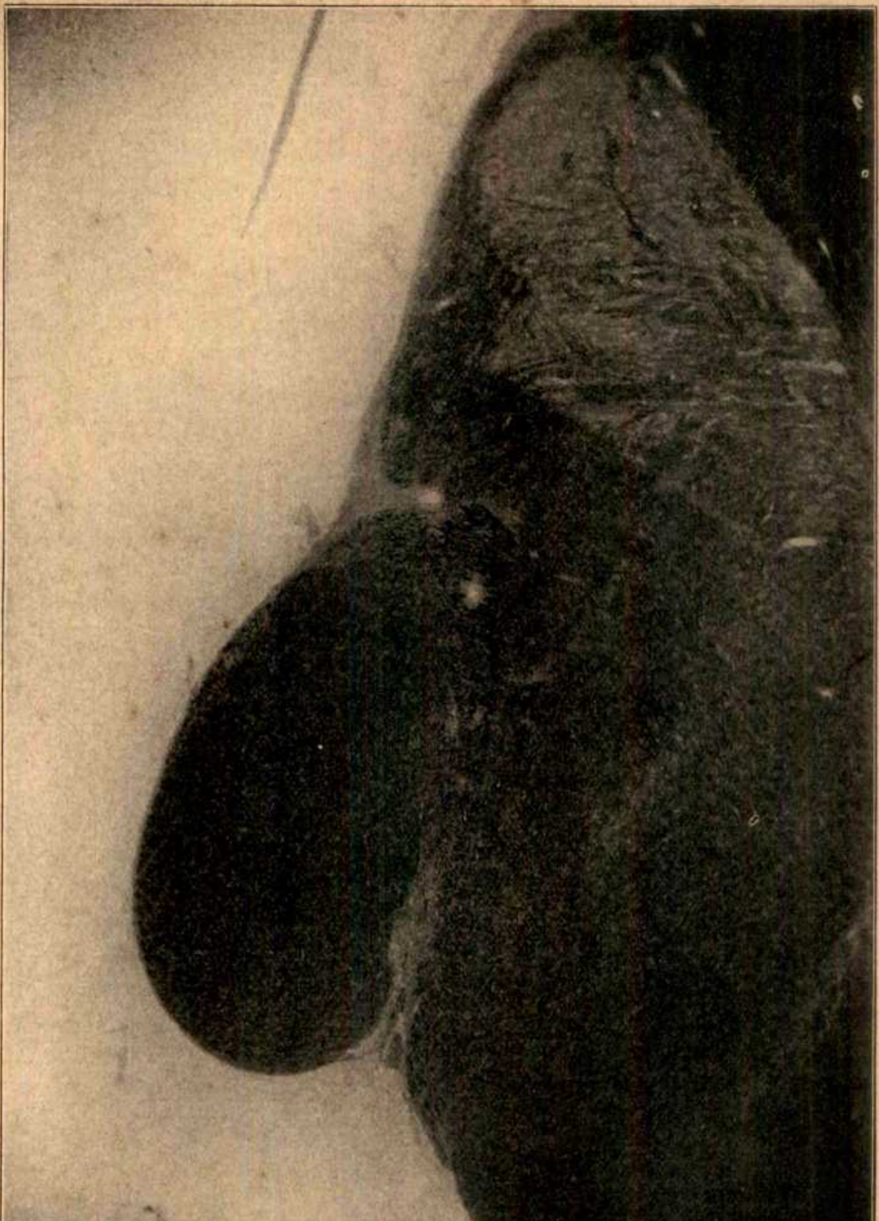

FIG 4.

Macacus rhesus.—Section through exit of V. The mesencephalic root had been divided intracerebrally, and the degenerated fibres can be seen leaving the pons with the *motor* root of the trigeminal.

involved the fibres of the fastigio-brachial system (Clarke and Horsley), from which bulbar collaterals proceed as well as other fibre systems. We have thoroughly examined the large mass of material at our disposal, and are certain that no collaterals proceed from the axones of the mesencephalic root to any nucleus lower than the oral plane of the vestibular nuclei.

Probst's view is repeated in another form by Lewandowsky [22] who, while opposing Probst's statements as to the termination of the supposed fifth-nerve collaterals, nevertheless ascribes to a descending bundle passing dorsally over the seventh nerve and ending ventrally of the nucleus of the solitary bundle an origin from the fifth-root region, and possibly from Kohnstamm's nucleus intratrigeminalis.

We have no doubt that the fibres observed by Probst and Lewandowsky are two different tracts, neither of which arises from the fifth roots. The first of these [see figs. 5 (*b*) and 6 (*b*)] consists of fine fibres, which by the lesion are caused to undergo retrograde degeneration backwards into the "gustatory nucleus" of Nageotte. Thus the section of the mesencephalon divides these neurones of the second order as they ascend from the nucleus of Nageotte to the thalamus. Hence, not only can they be traced by retrograde degeneration into the gustatory nucleus, but also upwards into the thalamus. They pass upwards in the reticular substance between Forel's bundle and the central grey matter lying dorsal and external to the remains of the posterior longitudinal fasciculus. Higher, the fibres pass into the lamina interna, and gradually into the inner part of the dorsal third of the nucleus lateralis.

The second bundle of coarser fibres described by Lewandowsky are internal, and, as he states, ventral in position to the grey matter surrounding the fasciculus solitarius [see figs. 5 (*a*) and 7 (*a*)]. These are, in fact, some of the most dorsal bundles of the substantia reticularis bulbaris, and terminate before the central plane of the hypoglossal nucleus is reached.

We have no evidence of the precise origin of these coarse reticular fibres of Lewandowsky, which must arise from cells at or above the level of the superior colliculi. They are efferent or descending fibres, as they do not degenerate upwards.

That these two tracts of fibres, Probst's and Lewandowsky's, have nothing to do with the fifth nerve is amply proved by our experiments, since we have in one series examples of all possible variations of the experimental conditions—i.e., complete section of the fifth mesencephalic

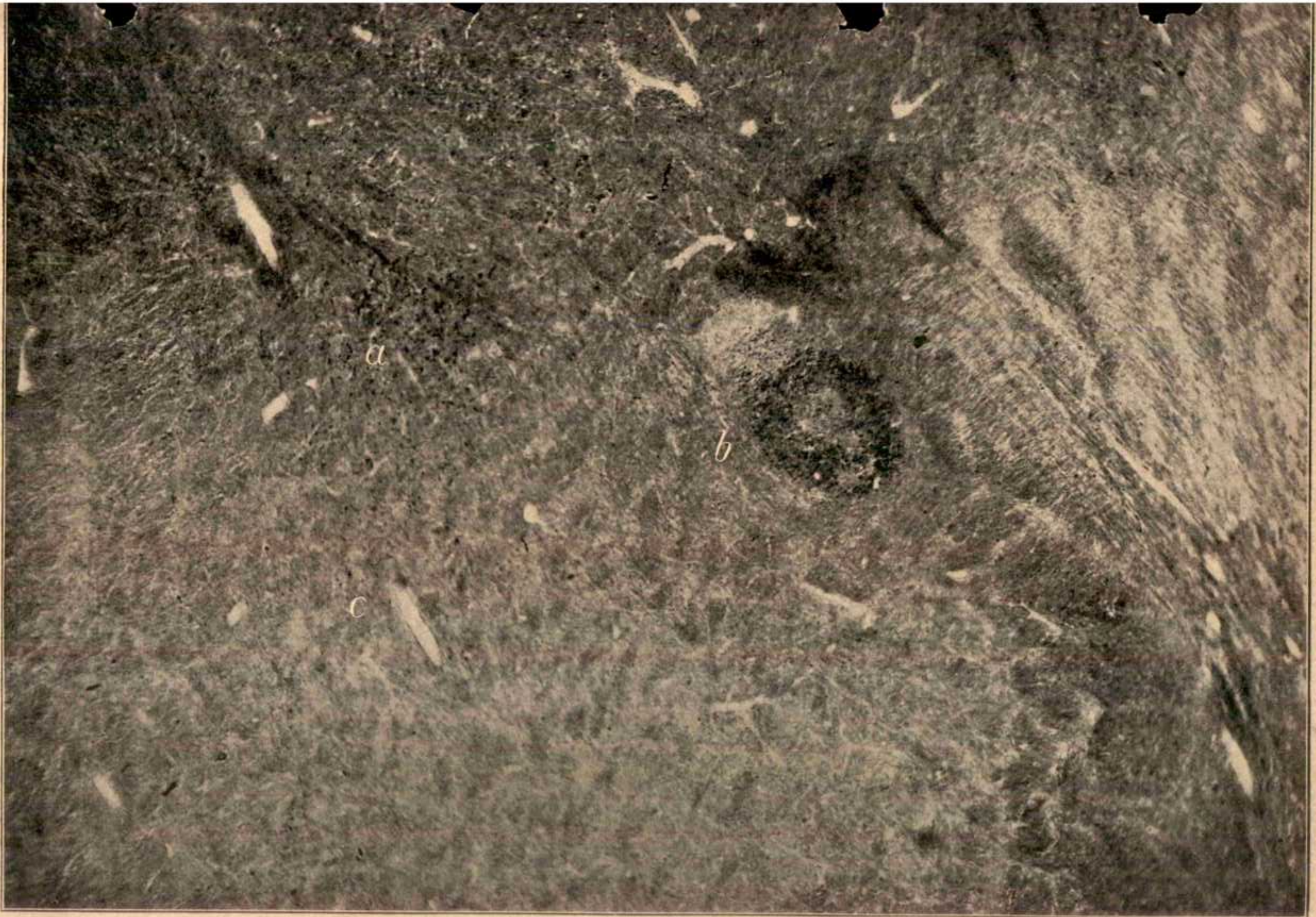

FIG. 5.

Macacus rhesus 204·09.—Section of mesencephalon caudal to fig. 4, and showing both tracts ascribed by Lewandowsky and [illegible]

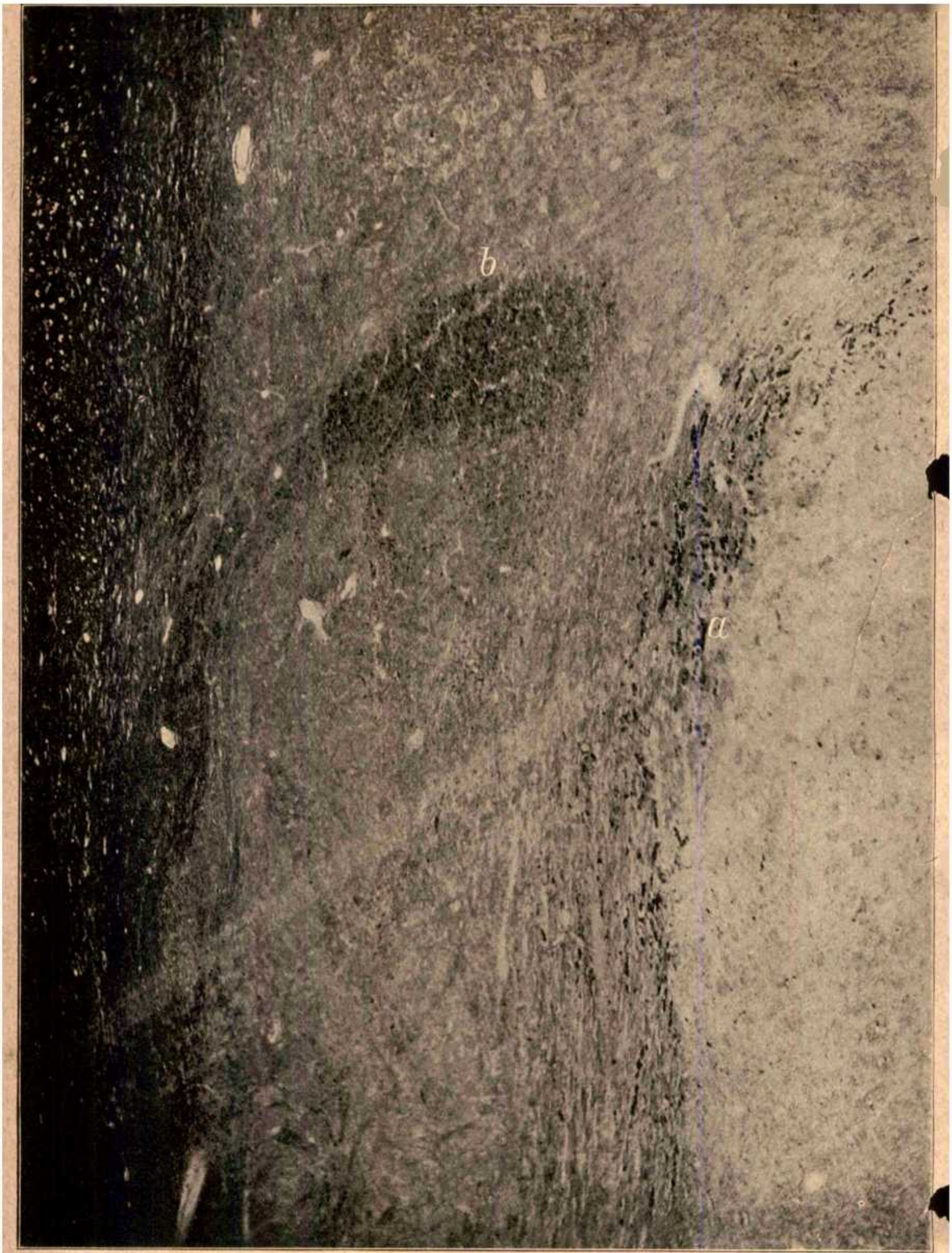

FIG. 6.

Macacus rhesus, 204·09.—Section of mesencephalon parallel to the interaural plane (Clarke and Horsley) in a case of division of the tractus mesencephalicus.

The coarse degenerated fibres of th[illegible] are seen at (*a*) descending to leave by the motor root. Outside these, and separated from them, are the [illegible]ded gustatory fibres (*b*).

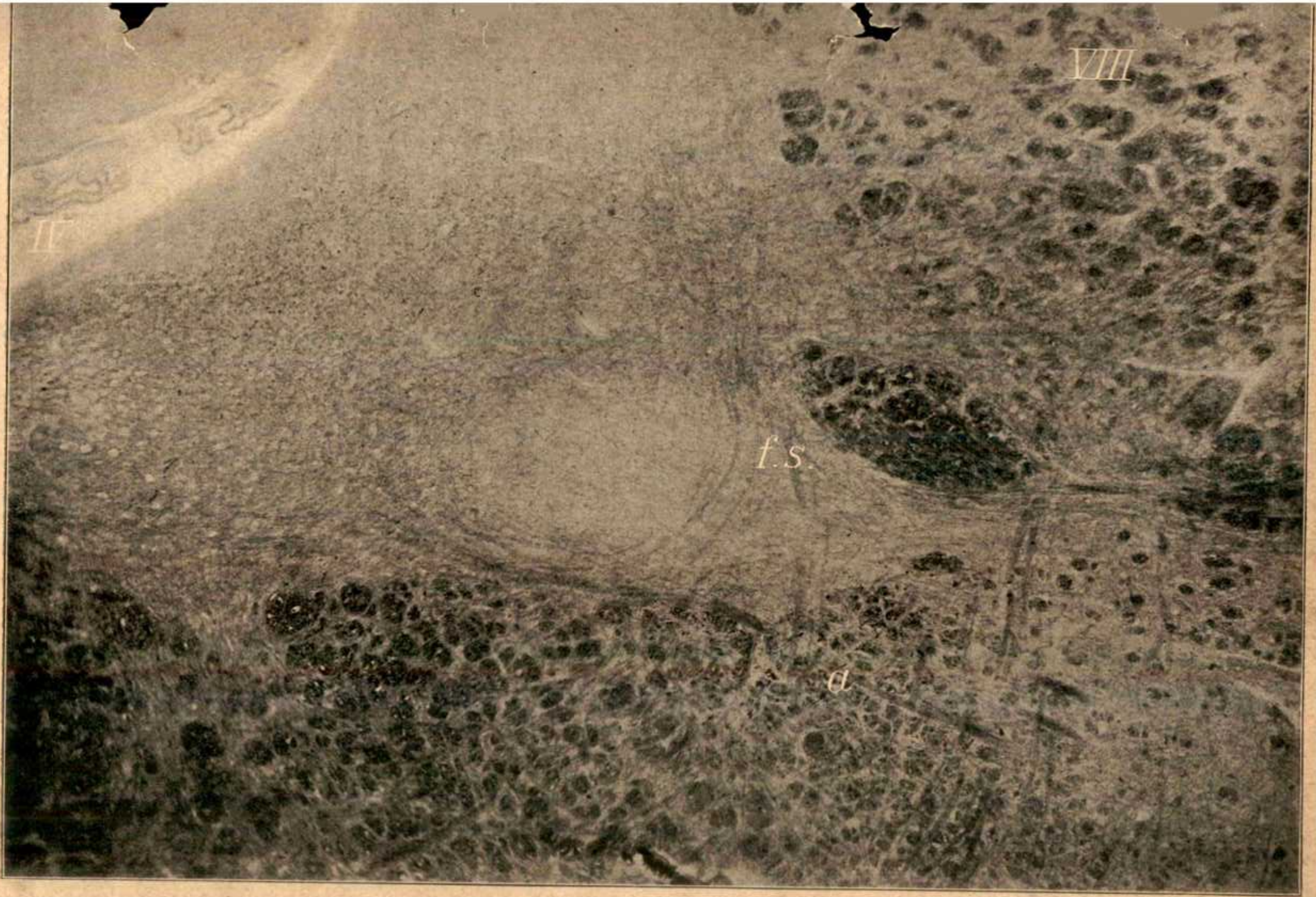

FIG. 7.

Cat.—Section of the vagal angle and lateral wall of the fourth ventricle (*IV*), showing the fasciculus solitarius (*fs*) and its nucleus. Below its nucleus are (*a*) the coarse degenerated fibres of Lewandowsky, occupying the upper and outer border of the pars reticularis. These fibres come from the neighbourhood of a mesencephalic lesion.

root without either of these tracts being degenerated, section of the root with both or only one tract degenerated, and degeneration of both tracts without section of the mesencephalic root of the fifth nerve.

In short, we have all possible control experiments, from which it is plain that neither the fine-fibred tract of Probst nor the larger-fibred reticular tract of Lewandowsky is formed by collaterals from the mesencephalic root of the trigeminus.

(2) *Supply of Collaterals to Motor Nucleus.*—The supply of collaterals from the mesencephalic root, which Cajal was the first to describe, is, of course, well demonstrated in Marchi preparations [see figs. 8 (rhesus) and 9 (man)]. All the collaterals are very fine, and form a network which stains intensely by this method.

(3) *The Continuation of the Axones from the Pons.*—We now approach what was originally the starting-point of the present investigation—namely, the destination of the centrifugal axones of the mesencephalic root after their exit from the pons. Physically, this can be investigated only in the manner we have used—namely, intracerebral section of the mesencephalic root, with subsequent examination of the degenerated fibres.

In addition, we examined, by the teasing method, the various nerves distributed to the ocular muscles, the sixth, fourth, and third, including the ciliary branches. In several experiments, considerable degeneration was found in the fourth nerve, but this was in every case the result of damage to that nerve in the course of the operation on the mesencephalon. The other nerves in the orbit were entirely free from degeneration, a result which confirms the observations of Kohnstamm and Quensel, who failed to find any chromatolysis of the characteristic cells of the mesencephalic root after removal of the orbital contents in animals.

As has already been indicated, Marchi preparations of the trigeminal nerve and its branches, from animals in which intracerebral section of this root had been performed, failed to demonstrate these fibres in any part of the trigeminal distribution peripheral to the Gasserian ganglion. They could be seen in the motor root as far as the level of this ganglion, but could not be found by teasing or by serial sections in the various peripheral branches.

In view of the fact that the conditions under which intracerebral degeneration develops are not precisely the same as those governing the degenerative changes in the peripheral nerves, it occurred to us that we ought to re-investigate the simple question of the degeneration of the

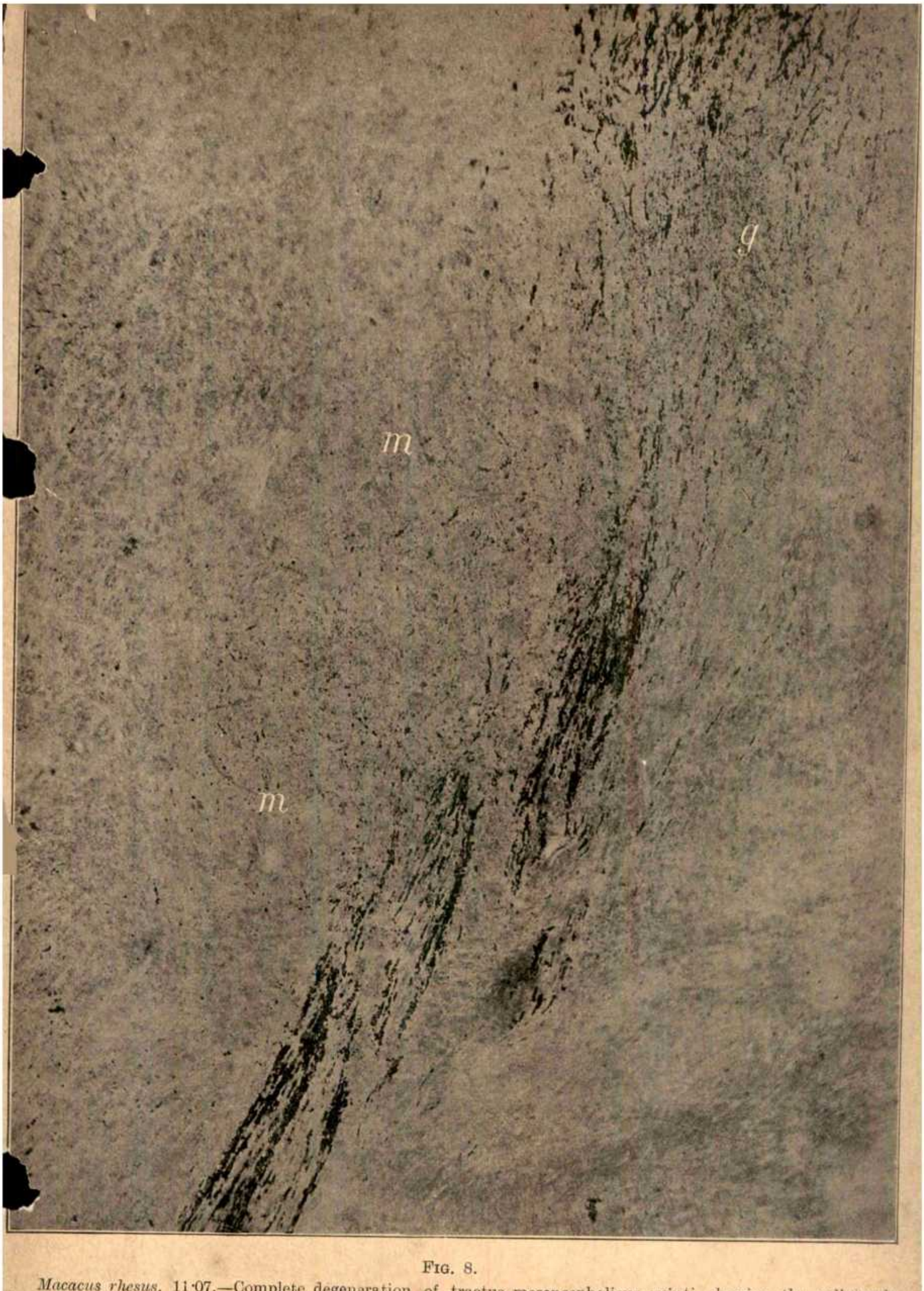

FIG. 8.

Macacus rhesus, 11·07.—Complete degeneration of tractus mesencephalicus quinti, showing the collaterals therefrom passing into the motor nucleus (*m m*). The latter nucleus lying between the letters *m m* is marked off by reason of the number of fine collaterals (degenerated) in it.

Above, at *g*, are seen the fine "gustatory" fibres passing backwards and outwards.

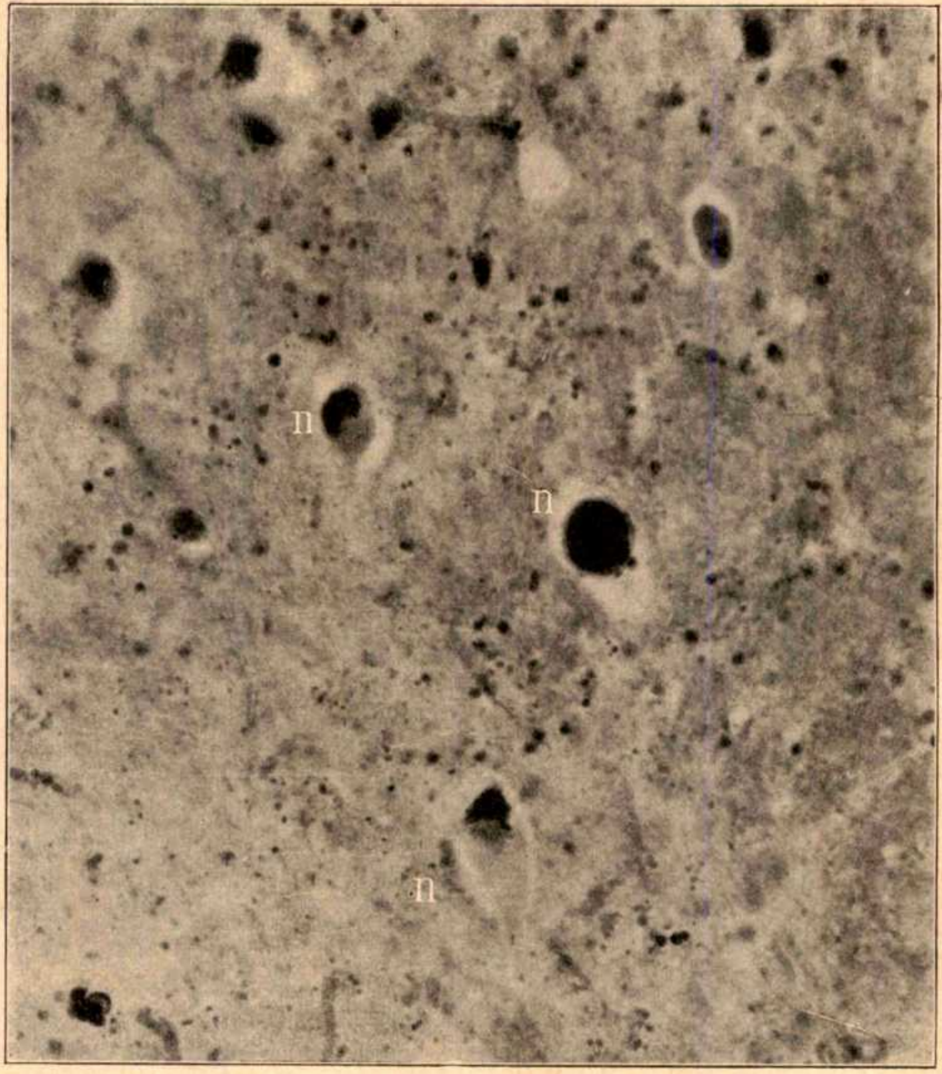

FIG. 9.

Man.—Collaterals (retrograde degeneration) in the motor nucleus of the fifth nerve consequent upon removal of the nerve six weeks before death. The nerve-cells (*n n*) contain much pigment, staining deeply with the osmic acid.

fibres of an efferent motor-nerve when they are divided from their nucleus of origin while still within the central nervous axis. To test this by a simple case, we made three experiments on the hypoglossal nerve—two in the cat and one in the monkey. The experiment was as follows: In the anæsthetized animal the cerebellum and bulb were both carefully exposed, a small knife was then introduced, parallel to the plane of the fourth ventricle, through the tubercle of Rolando. The direction given to the knife was such that the hypoglossal fibres running through the tissues of the bulb were divided close to their nucleus. The animals were killed fourteen days after the operation. In each case the peripheral nerve showed a proportionate number of completely degenerated fibres. It is clear that a simple efferent nerve, like the hypoglossal, degenerated completely when its axones are divided in their intracerebral course. It seemed to us that the apparent anomalous fact of the mesencephalic trigeminal fibres was susceptible of three different explanations: (*a*) That the fibres are distributed to some other structure—e.g., the otic ganglion. (*b*) That they lose their medulla, and are continued to the periphery as non-medullated fibres. (*c*) That they end in the Gasserian ganglion.

In order to test the first assumption, a further series of experiments (three in number) were made in which, after a mesencephalic lesion had been made as above stated, the Gasserian ganglion was removed *en bloc* with the contents of the spheno-maxillary fossa and serial sections cut. In these again the degenerated fibres could not be traced beyond the level of the Gasserian ganglion, and the otic ganglion was found to be quite free from any such fibres.

The second explanation (*b*) is rendered improbable by the fact that all the fibres of the various peripheral branches, as seen in teased specimens stained by osmic acid, appear to be medullated. It would appear then that the third explanation (*c*) must be accepted as the most probable—namely, that the efferent fibres of the mesencephalic root end in the Gasserian ganglion. At first sight this mode of termination would seem to be incompatible with the fact stated above, that some chromatolysis of the cells of origin occurs after avulsion of the peripheral branches of the inferior division of the trigeminal. But on this point Warrington [37] has shown by section of anterior and posterior roots respectively that the chromatolytic changes resulting therefrom affect not only the cells in direct association with the fibres divided, but also other cells forming part of the same nerve centre. For all these reasons we prefer to leave this matter at this point.

III.—*Examination of Centripetal Axones.*

There is abundant evidence that the mesencephalic root contains, in addition to the centrifugal fibres described above, a considerable number of centripetal fibres.

If this root is cut across at the level of the posterior corpora quadrigemina, sections of the mid-brain cephalad to the lesion show the presence therein of a varying number of fine degenerated fibres (fig. 10). The question immediately presents itself: Are these fibres derived from cells in the brain-stem, or from those of the Gasserian ganglion?

The idea that some of these may be fine collaterals resulting from the divided axones of the characteristic globular cells we owe to Van Gehuchten. Our method does not permit of expressing an opinion as to whether any of the degenerated fibres we have observed originate in this way. We have, however, the proof that many of the ascending fibres in the root come from the cells of the Gasserian ganglion. Upon this question, which has received direct attention from van Londen [35] and Bregmann [4], who each observed by the Marchi method degenerated fibres in the tract after section of the trigeminal proximal to the ganglion, and from Probst, who observed the same after a lesion of the mesencephalon at the level of the exit of the fourth nerve, we have accumulated a large amount of material of the following kinds:—

(*a*) Degeneration following removal of Gasserian ganglion: (**α**) Man. (*β*) Other animals.

(*b*) Intracerebral section of the mesencephalic root: (*α*) At level of exit of the fourth nerve. (*β*) At level of anterior border of posterior colliculus.

(*a*) *Degeneration following Removal of Gasserian Ganglion.*

(*α*) *Man.*

In a patient (H.) in whom the Gasserian ganglion was removed by one of us (V.H.) in 1907 at the National Hospital for the Paralysed and Epileptic, and who, shortly after her discharge from hospital, contracted a rapidly fatal pleurisy, examination of the brain by the Marchi method revealed the following—(death occurred six weeks after the operation). As shown in the photograph (fig. 11), the trunk of the nerve in its transit through the pons displayed complete degeneration—i.e., not only of the fine afferent fibres, but also a retrograde degeneration of the motor root. As the opport[illegible]racing these degenerations in man are infrequent,

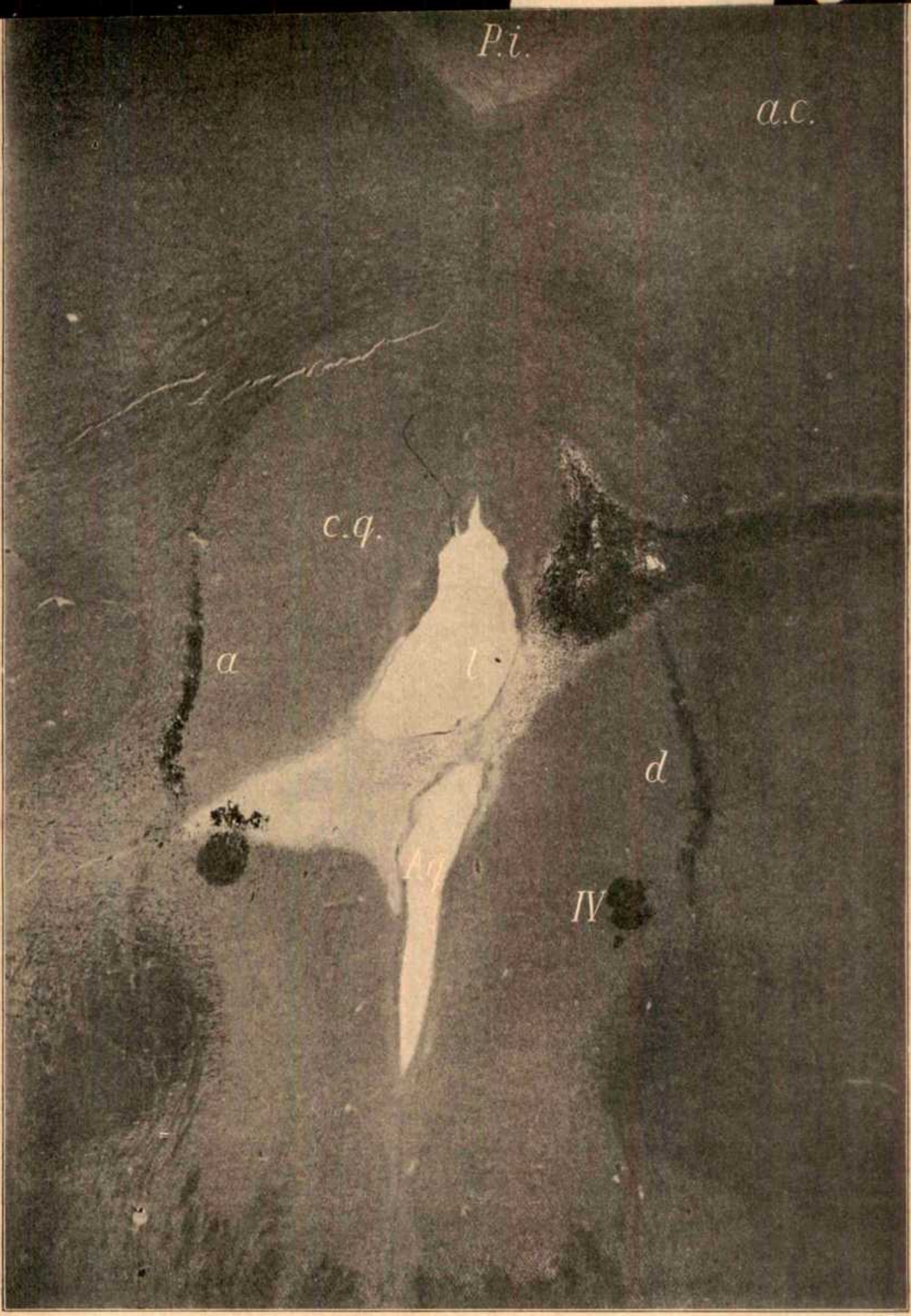

FIG. 10.

Macacus rhesus.—Section of mesencephalon through the anterior colliculi and parallel to the inter-aural plane.

In this experiment the knife passed across the aqueduct obliquely, thus dividing the tractus mesencephalicus quinti, on one side at the anterior region of its origin, and at the posterior (caudal) on the other.

Consequently the afferent (including retrograde degeneration) and efferent fibres respectively are degenerated.

Aq = aqueduct, *l* = lesion, *c g* = central grey, *a c* = colliculus anterior, *p i* = glandular pinealis, *a* = ascending fibres, *d* = descending fibres.

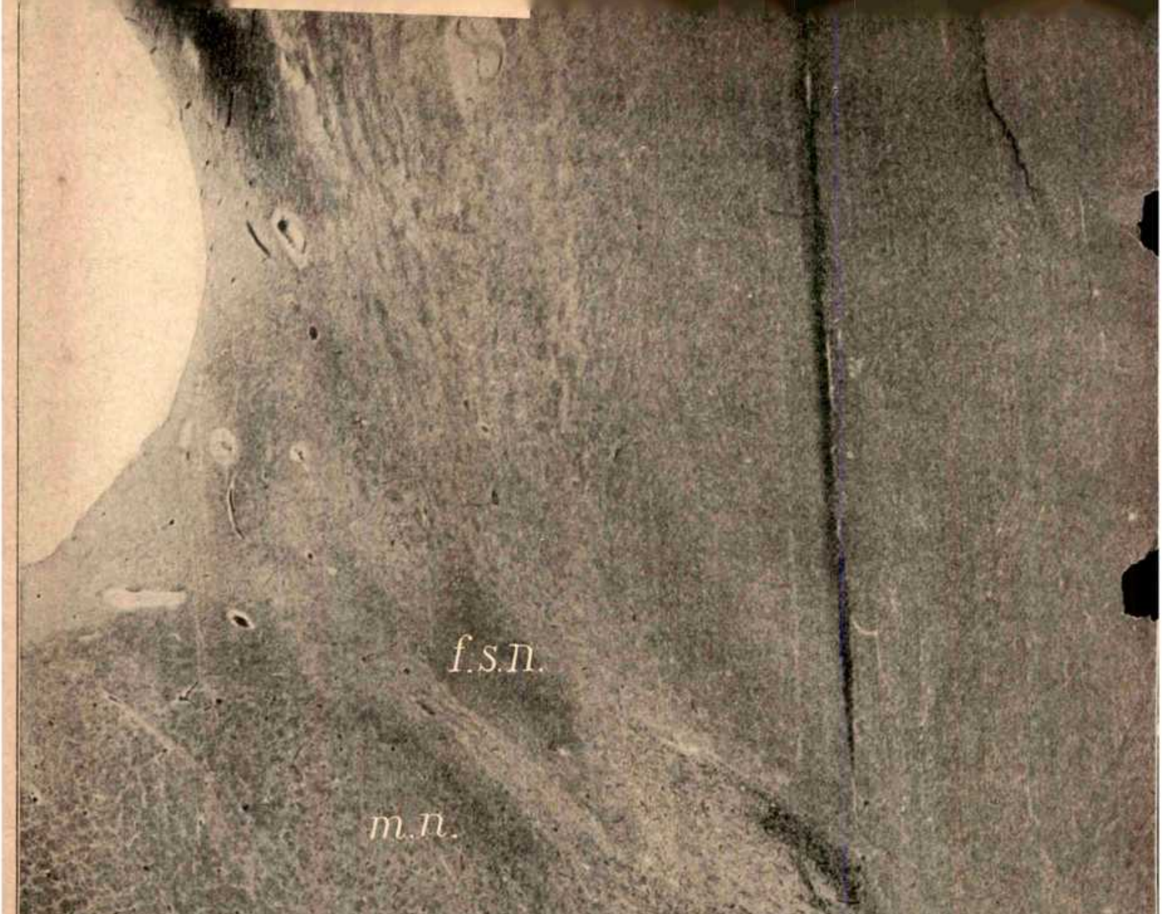

FIG. 11.

Man.—Degeneration of the fifth nerve consequent on removal of the Gasserian ganglion and roots six weeks before death, showing relation of trigeminal afferent fibres to the fasciculus solitarius.

V c = commencement of the trigeminal sensory nucleus into which enter the degenerated fibres of the nerve root.

m n = the motor nucleus of the fifth nerve.

f s n = fasciculus solitarius commencing from the gustatory nucleus.

we venture to add a general description to the special notes made on the mesencephalic root, and we will commence with this retrograde degeneration of the motor root.

(*a*) *Motor root* (Efferent fibres).

The retrograde degeneration of the motor fibres consists of comparatively fine granules. This may possibly be due in part to the considerable period elapsing between the operation and the time of death. The degeneration can be traced as fine collaterals in a considerable belt lying along the outer border of the motor nucleus (Ramon y Cajal's network). From this they are disseminated throughout the nucleus (see fig. 9).

(*b*) *Sensory root* (Afferent fibres).

The afferent fibres which make up the large volume of the nerve roots begin to break up into bundles as soon as they enter the outer part of the reticular substance of the pons, and at the level of the upper border of the trapezium islands of nuclear substance (convolutio quinti) begin to show themselves. Of these, one in particular, in the direct line of entry of the nerve root, and situated above and to the outer side of the dorsal end of the motor nucleus, is rendered noticeable by the particularly dense felt-work of fine fibres composing its periphery. Passing onwards, the finest fibres, or collaterals from them, turn inwards and enter the small-celled angular nucleus of the eighth nerve.

Many of the fibres go straight up to the angle of the fourth ventricle, and thence are continued as fine axones up the mesencephalic root. These are shown in detail in the accompanying photographs.

That they were not observed by the earlier investigators was probably due to imperfect staining. In their ascent in the root, they gradually come to occupy the median half of its breadth (see fig. 12 *a f*). They can be traced up as far as the central plane of the anterior colliculus, where they are seen as a single vertical row of fibres at the border of the central grey matter at its widest part. It is interesting to note that, in accord with our experimental results, the characteristic spheroidal cells are notably diminished in number and in size on the operated side. On the other hand, the cells of the locus cæruleus in this case show no difference at all on the two sides (fig. 12), an observation which also agrees with those we have made after experimental avulsion of the nerve roots in animals.

The present case afforded also a good opportunity for examining the relation of the afferent fibres of the fifth nerve to the gustatory nucleus

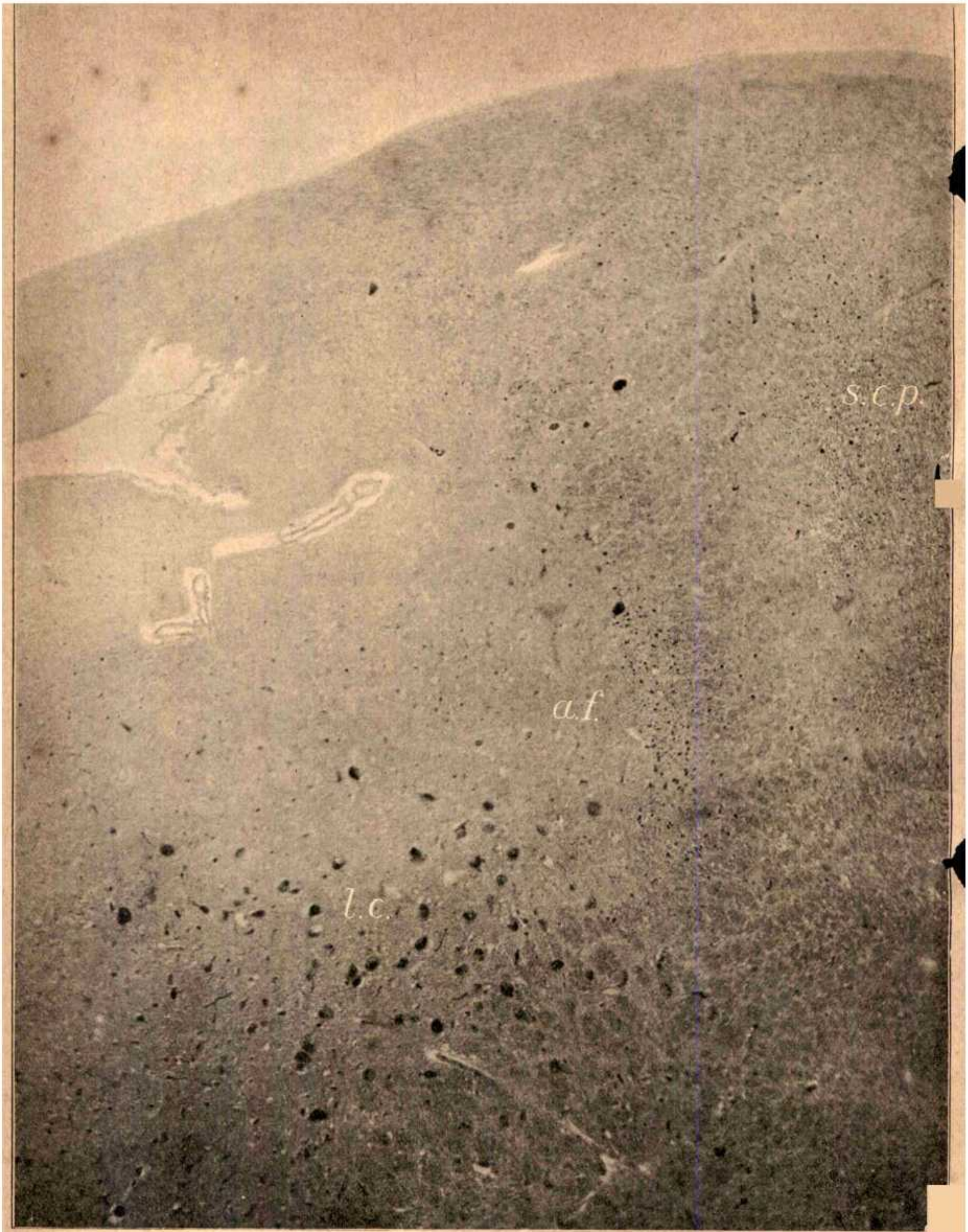

FIG. 12.

Man.—Transverse section of lateral angle of mesencephalon from a case of removal of the Gasserian ganglion and fifth nerve six weeks before death, showing (1) the fine afferent fibres in the mesencephalic root; (2) that these are grouped in the mesial half of the tractus as they ascend under the tectum; (3) that the cells of the locus cæruleus are unaffected.

l c = locus cæruleus cells deeply pigmented, but normal.

a f = placed just on the inner border of the mesial half of the tractus mesencephalicus indicates the degeneration in this of the afferent fibres.

s c p = pedunculus cerebelli uperior.

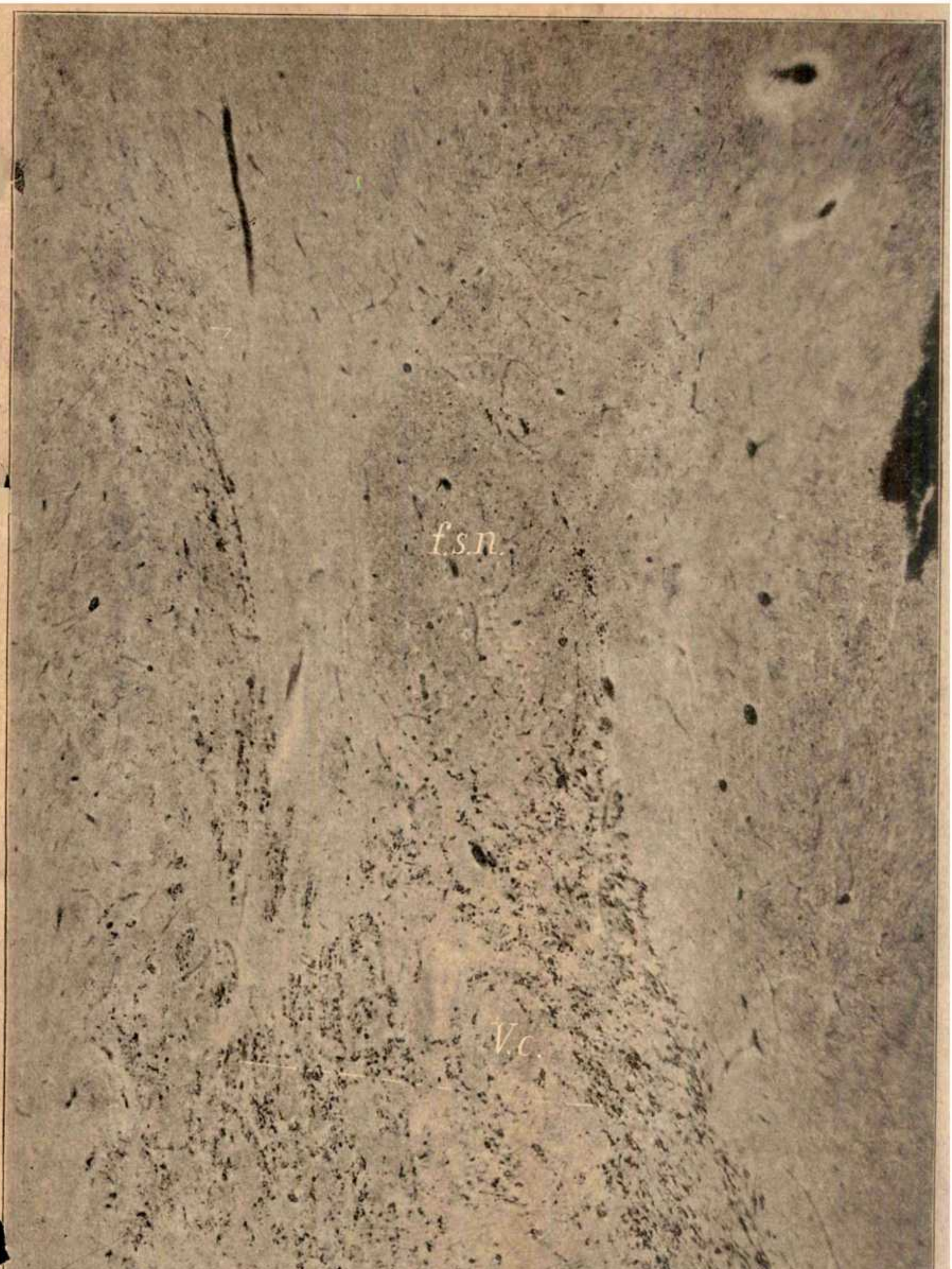

Fig. 13.

Man.—Section of the mesencephalon caudad of Fig. 11, showing the distribution of the trigeminal fibres ventral to the fasciculus solitarius.

v c = the sensory nucleus (convolutio quinti) of the fifth nerve, with numerous degenerated fibres reaching to the commencement of the fasciculus solitarius from the "gustatory" nucleus *f s n*.

of Nageotte and the fasciculus solitarius. Fig. 13 shows fibres passing into and through the outer part of this nucleus and fasciculus. A few fine collaterals can be observed in the upper part of the nucleus (*f s n*), thus demonstrating the degree of the supply of this part by the fifth nerve. This is the superior part of the gustatory nucleus of Nageotte [25].

Ventral to this, the substantia gelatinosa of the sensory nucleus of the fifth nerve extends upwards and inwards like a sharp wedge and forms the outer limit of the substantia reticularis. The fibres running through this are grouped in bundles separated by large areas of grey matter, in which they break up into fine collaterals. This portion of the fifth sensory nucleus is, lower down, sharply marked off from the grey matter surrounding the fasciculus solitarius by root fibres of the ninth nerve. The general outline of the area occupied by the nerve is, roughly speaking, a triangle, the base of which is formed by the crescentic margin which is conventionally used to represent the spinal root of the fifth nerve in most drawings of this region. This triangular outline is traceable right through the bulb to below the level of the nucleus ambiguus, caudal to which the reticular fibres certainly diminish in number, and an approach to a crescentic shape becomes more evident. Fine collaterals are supplied to the nuclei which border the nerve in every direction—namely, those of the cranial nerves from the sixth to the tenth inclusive (? other nuclei).

Crossing of Fibres (Sensory and Motor).

The crossing which the earlier writers (from Kölliker to Bruce) thought to occur, and by which fibres, both motor and sensory, of the fifth nerve of one side entered or left the roots of the opposite side, was never, in our view, justified by the facts. The nearest approach to crossing which we have seen in our specimens, either in man or the lower animals, has been merely the supply of coarse or fine collaterals to the nucleus of the sixth nerve on the same side.

This, however, is not the view taken by van Londen [35], who thought he had observed in rabbits that some of the fibres in the sensory root passed across the raphe in a plane corresponding to the level of the locus cæruleus.

(β) *Centripetal Fibres as observed in Animals other than Man after Lesions of the Nerve outside the Brain.*

In the cat and Rhesus monkey the same facts were observed as in man, with the additional interest of proving the source of the fine afferent axones in the mesencephalic root to be the cells of the Gasserian ganglion. Thus, in two sets of animals observations were made according as the fifth nerve was divided proximally or distally to the ganglion respectively. In the former series the afferent fibres were degenerated, in the latter they were not. The degenerate axones were almost all of fine calibre, only a few of medium size being observed.

(*b*) *Degeneration of Centripetal Axones after Intracerebral Section of the Mesencephalic Root in Animals.*

In the large series of experiments in which we have made a lesion of the mesencephalon either below, at the point of exit of the fourth nerve, or at various points in the mid-brain up to the posterior margin of the anterior colliculus, we have obtained absolutely constant results. The root, under these conditions—namely, intracerebral section—contains numerous fibres running centripetally, consisting for the most part of fine axones, but including others of a medium size. The origin and course of the fine fibres we have just discussed. As regards the medium-sized fibres, it is readily conceivable that these may be stouter centrifugal axones of the globular mesencephalic cells undergoing "retrograde degeneration." At present we know of no means whereby to differentiate between these.

IV.—*Physiological Tests in Animals in which Intracerebral Division of the Mesencephalic Root was Performed.*

Our experiments on the matter of function of the mesencephalic root have been negative as far as any direct result from the lesion is concerned. In the first animals experimented upon, we investigated the sensory surfaces supplied by the fifth nerve—e.g., the conjunctivæ, skin, and nasal and buccal mucous membranes—without being able to discover that the destruction of the mesencephalic root caused any definite functional loss. Similarly there was no obvious loss of power of mastication on either side, the jaw opening without any lateral deviation. Finally, stimulation of the root on the cut surface of the mesencephalon produced no effect on the muscles of mastication, unless the excitation spreads to the pontine masticatory nucleus.

Cajal suggests that the function of the mesencephalic root is to act as a relay in connexion with stimuli emanating from the cerebral cortex, but no evidence has yet been adduced in support of this.

V.—*Summary of Results.*

(1) The mesencephalic root of the fifth nerve contains both centrifugal and centripetal fibres.

(2) The centrifugal fibres are the axones of the characteristic globular cells.

(3) Practically all these axones leave the pons by the motor root of the fifth nerve.

(4) There are some grounds for believing that some of these end in the Gasserian ganglion.

(5) But avulsion of the peripheral branches of the inferior division causes chromatolysis of the characteristic cells, a result suggesting that these axones run in the peripheral branches, though examination by the Marchi method has failed to reveal them.

(6) There is no evidence that the cells of the locus cæruleus form part of the axonal system of the trigeminal nerve.

(7) The tracts described by Probst and Lewandowsky as consisting of collaterals derived from the mesencephalic trigeminal axones, and establishing connexions with the nuclei of the eighth to eleventh cranial nerves, have no relation to the fifth-nerve system.

(8) The centripetal fibres of the mesencephalic root consist of fine axones, which are in the large majority derived from the cells of the Gasserian ganglion. Some may be derived as collaterals from the centrifugal axones (Van Gehuchten).

(9) All the evidence at our disposal is in favour of the view that the intracerebral connexions of each fifth nerve preserve a strictly ipsilateral distribution, and negatives absolutely the existence of crossed roots as postulated by earlier authors.

(10) There is no evidence that the mesencephalic root is connected in any way with the innervation of the extrinsic muscles of the eyeball or palate.

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STRANGULATION OF THE NERVI ABDUCENTES BY LATERAL BRANCHES OF THE BASILAR ARTERY IN CASES OF BRAIN TUMOUR.

With an Explanation of some Obscure Palsies on the Basis of Arterial Constriction.[1]

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INTRODUCTION.

DIPLOPIA so often occurs in cases of intracranial tumour that one feels at times almost justified in including this symptom with the manifestations more or less commonly ascribed to the general increase of pressure—headache, choked disc, vomiting, colour inversion, extracranial venous stasis, convulsions, dizziness, bradycardia, and the like.

That oculomotor or abducens palsies may represent true "neighbourhood" symptoms in case the lesion has directly affected either the nerve centres or the nerves themselves in their intracranial course needs no comment, for the rule applies to other cerebral nerves as well as to the third and fourth pairs. It is a matter of common knowledge, however, that ocular palsies, either stationary or fluctuating in their intensity, particularly those manifested by a convergent squint, are so often misleading from the standpoint of topographical diagnosis that they have come to be classed with the "false localizing signs" of tumour.

Possibly the most complete discussion of the diagnostic confusion which may arise from this and other sources occurs in Collier's admirable paper [3]. False localizing signs, attributable in most instances to the "indirect intracranial results of intracranial new growth," were present in 12·5 per cent. of the 161 cases forming the basis of his studies. He emphasizes the fact that an "indirect" paralysis affects the abducens more often than any other cerebral nerve, and in twelve of his cases some affection of the sixth pair accompanied tumours situated above the tentorium. The paralysis was unilateral in six instances and bilateral in six, and when unilateral was right-sided in four cases and left-sided in two. In two instances, furthermore, paralysis of the oculomotorius (bilateral in one case) occurred secondary to paralysis of the abducens (bilateral in the other case), the nerves in each instance being affected earlier upon the side of the lesion, which in one instance proved to be a right subcortical tempero-sphenoidal tumour, and in the other a large left prefrontal growth.

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[1] Presented at the meeting of the American Neurological Association, Washington, May 2, 1910.

The usual explanation of these "distant" abducens lesions is based on the presumption that the sixth nerves, owing to their long course and exposed position, are particularly susceptible to injury through compression against the cranial base. Collier is not thoroughly satisfied with this view, and submits, as a more likely explanation, the fact that the abducentes represent the only cerebral nerves which pursue a longitudinal rather than an oblique or transverse course from their superficial origin in the brain-stem to their dural foramina of exit. On this basis the shifting backward of the brain-stem—indicated by the well-recognized moulding of the medulla and cerebellar margin in the foramen magnum in cases of tumour (foraminal herniation)—would exert greater traction upon those nerves directed antero-posteriorly than upon those having a transverse course. To quote his exact words:—

> If the paralysis of these nerves is the result of shifting backwards of the brain-stem from supratentorial pressure, the effect being traction upon the nerves attached to the brain-stem, in proportion as their direction is more nearly a frontal-caudal direction, then the shifting backwards of the brain-stem would cause paralysis of the sixth nerve first, then of the third nerve, and lastly of the seventh and eighth, while the nerves which are transversely directed, or with sinuous course, would be little affected. Such traction would obviously be first manifested upon the side where supratentorial pressure is greatest—that is, upon the side of the lesion.

Even this ingenious hypothesis of Collier's does not give entire satisfaction, for, granting the downward dislocation of the brain-stem which is inevitable with any considerable increase of supratentorial pressure, it is nevertheless difficult to see, in view of the near proximity of their points of external origin, how this traction from dislocation could paralyse the abducens on one side alone without an extreme degree of lateral deformation of the pons. It is difficult, too, to reconcile this explanation of a palsy produced by the gradual traction to which the nerves would be subjected under these circumstances with the well-recognized fact that motor-nerves may undergo an astonishing degree of stretching and elongation without any observable interruption of function. This is particularly well seen in cases of cerebello-pontine tumour in which there may not be the slightest evidence of weakness of the facial muscles unless the condition is far advanced, and yet post-mortem the seventh nerve may be found wrapped around the circumference of the tumour, flattened and drawn out to more than twice its normal length. The same thing may be seen in the case of the third and sixth nerves, which, much elongated and flattened, may similarly encircle a slowly enlarging infundibular tumour without any profound disturbance of ocular movements.

Peripheral motor-nerves therefore do not seem readily to lose their power of transmitting impulses when subjected to a slow process of elongation, such as would be occasioned by even the direct action of a new growth. We shall learn, too, from the study of our own cases that, in the absence of any direct affection of the nerves themselves or of their centres, a subtentorial (cerebellar) lesion which actually pushes the pons forward, with an effect consequently on the sixth pair the reverse of stretching, may nevertheless lead with even greater likelihood to a palsy of these nerves.

CHARACTER AND SOURCE OF MATERIAL.

For the past five years my assistants and myself have been given the privilege by the pathological department of the hospital of making our own first-hand studies of the central nervous system of all patients who succumbed to the effects of intracranial lesions while resident under the surgical service. In addition to these opportunities we have had the good fortune to secure almost without exception the brains of all patients who have died elsewhere than in the hospital at varying periods after palliative tumour operations.

We have thus in the end come into possession of the brains of some forty of our 130 cases of operations for presumed brain tumour; and, in addition to this material, the tissues from a nearly equal number of cases which have died in the hospital from miscellaneous intracranial lesions—vascular disease, hydrocephalus, trauma, and the like—have been available for control of the matters under consideration.

It has been our invariable custom thoroughly to harden all brains *in situ* by carotid injections of formalin, so that the normal configuration of the parts should be absolutely preserved. Considerable deformation is an inevitable consequence of removing brains under tension while in their original soft condition, and the additional custom of allowing the tissues to harden while suspended by the vertebral arteries would certainly destroy the neuro-vascular relationship to which we especially desire to call attention. Our main object in choosing this method of fixation has been to study the topographical relations of the intracranial lesions in the hope of throwing some light on their gross mechanical effects, rather than to investigate their histological characteristics or resultant degenerations—studies for which we are not particularly well trained.

We have endeavoured in each case to correlate the post-mortem findings with the ante-mortem symptomatology: first, by determining what localizing manifestations might have been expected from the given lesion and comparing them with the positive clinical findings; and, second, by attempting to determine the cause for such obscure or "distant" symptoms as had been recorded in the anamnesis or made out in the examination.

Naturally in this fairly large series of cerebral lesions there were a number of advanced cases in which so-called false localizing signs on the part of the ocular nerves had been observed, but, inasmuch as many of the tumours proved to be subtentorial, we were at first led to believe that the recorded periods of diplopia or the actually observed strabismus were due to a direct affection of the nuclei or to a possible stretching of the nerves, though neither of these interpretations explained the symptoms in all cases to our entire satisfaction.

PRIMARY OBSERVATION.

Our suspicions that *arterial constriction* might possibly account for these "distant" symptoms in certain cases were first aroused in 1909 by the examination of the brain of a patient who for years had suffered from typical, though long unrecognized, uncinate gyrus attacks with fluctuating periods of left hemianæsthesia and hemianopsia (supposed to be hysterical), and, during the last year of her life, from recurring diplopia due to periods of weakness of the right external rectus. The brain showed (fig. 1) that a soft gelatinous growth extending from the uncinate region into the lateral recess had pushed the right abducens backward in such a way that it had become caught by and kinked around the right *A. auditiva interna.* When the encircling artery was lifted from its bed it showed not only a transverse constriction of the nerve, but also a deep grooving of the subjacent pons, much as though an elastic band had been stretched around the brain-stem. Interesting, too, was the fact that the right oculomotorius (fig. 1), which was completely surrounded by the soft growth and much flattened, had never shown any clinical evidences of weakness, so that the conjecture was natural that the abducens palsy was more probably attributable to the mechanical constriction than to any possible compression from the growth.

This finding led to a review of the other brain-stems at our disposal, and although in some of them the vessels had been stripped away after the first gross external examination, or the tissues cut in such fashion as to prevent a satisfactory examination for this particular neuro-vascular relationship, nevertheless in a large number of them the essential structures were preserved, showing in the majority a constriction often bilateral and at the same time similar to or even more marked than that observed in this first case. All of the brains acquired during the past year have naturally been investigated with this particular point in view.

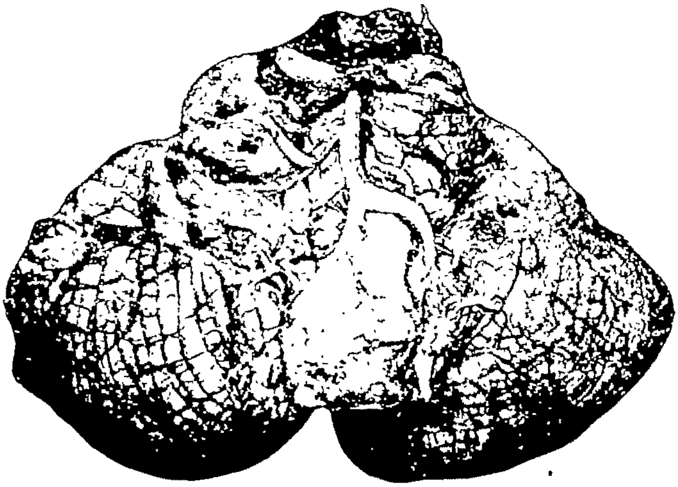

FIG. 1.

No. 10, Table I.—Brain-stem from first case observed. A gelatinous (degenerated) tumour of thirteen years' duration arising from the temporal lobe and spreading backward into the right lateral recess. Uncinate gyrus symptoms with right hemianopsia, right hemianæsthesia and right abducens palsy, all fluctuating in degree.

Note right third nerve flattened in tumour, but with no palsy, whereas the sixth is caught and constricted by right *A. auditiva int.*, over which it is buckled by pressure of tumour. Left *A. auditiva int.* has deeply grooved pons, but the nerve lay superficial to it. *Aa. cerebelli inf. ant.* both cross the pons caudal to the sixth pair.

Such a vascular strangulation of the abducens, needless to say, cannot occur unless the transverse arteries cross the pons superficial to the nerves, and, as will be seen, this is not the relationship which is usually given. As a matter of fact, the subject does not seem to have been given any especial consideration by anatomists, nor is there any reason why it should have been.

ANATOMICAL NOTES.

The fibres of the sixth pair emerge from the rhombencephalon, cephalad to the junction of the medulla oblongata and the pons, in a flat bundle consisting of from fifteen to eighteen small separate filia radicularia, which, as a rule, soon unite into the more or less rounded or flattened bundle characterizing the nerve in its longitudinal intracranial course.

The branches of the basilar artery (the only vessels which we need consider in relation to the sixth pair) pass transversely across the pons in a direction more or less at right angles with that taken by the abducentes. The two branches which come into direct relation with the nerve are: (1) The *A. cerebelli inferior anterior*, which passes outward and backward across the crus cerebelli, to be distributed to the anterior border of the under surface of the cerebellum, anastomosing with the posterior inferior cerebellar branch of the vertebral; and (2) the *A. auditiva interna*, which may either arise as a separate branch from the main basilar trunk or else through the bifurcation of the *A. cerebelli inferior anterior*. An average relationship is well shown in fig. 2.

Of the anatomies which I have consulted:—

Gray [4] does not mention the relationship of the inferior cerebellar artery to the nerve, but pictures (fig. 401) the nerve as superficial.

Quain [11] likewise does not mention the relationship, but also pictures (fig. 346, vol. ii, part 2, p. 412) the nerve as superficial.

Spalteholz [16] also makes no mention of the relationship, but pictures the nerve (p. 399) emerging between the *A. cerebelli inferior anterior* and the *A. auditiva interna* (an arrangement similar to our fig. 2, and one which would permit of strangulation of the nerve, by the larger artery, as in the conditions we are describing).

Henle [6] does not mention the relationship, but pictures (p. 125) the *A. auditiva* as superficial to the nerve, and the *A. cerebelli inferior anterior* as too far forward (i.e., arising near the trigeminal root) to bear any relation to the abducens. Practically this same picture occurs in Merkel's "Handbuch der Topog. Anat." (Braunschweig, 1885-90, vol. i, p. 143, fig. 83), and in Merkel's edition of Henle (4^te Auf., 1901, p. 433 of Atlas).

Sappy [15] does not mention the relationship, but pictures (fig. 372) the arteries as superficial to the nerves at their points of emergence—a situation, in other words, at which they could easily escape from the effects of constriction.

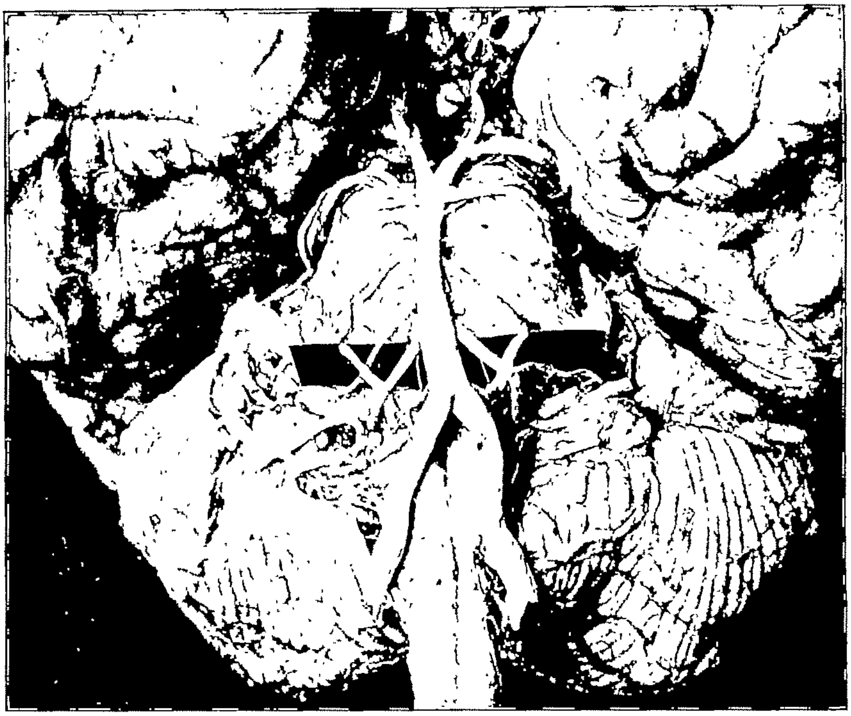

FIG. 2.

No. 36, Table II.—Brain-stem from a case of "pseudo-tumour" cerebelli (arteriosclerosis and nephritis causing cerebral œdema with typical pressure symptoms), showing a fairly normal distribution of the vessels, with minor anomalies (strip of black paper inserted under structures concerned).

Note: (1) Left *A. cerebelli inf. ant.* is superficial to but has not grooved the nerve, and after crossing it gives off the left *A. auditiva int.* A small (undescribed) minute arterial twig passes tailward from the *A. cerebelli inf. ant.* and has left a slight oblique groove in the left abducens.

(2) Right *A. cerebelli inf. ant.* is also superficial, and does not groove the right abducens; the anomalous twig is also present here, but does not overlie the nerve. The right *A. auditiva int.* arises as a separate vessel, and the nerve emerging between the two arteries lies superficial to it.

(3) The *A. cerebelli sup.* and the *A. cerebri post.* are widely separated. (The oculomotor nerves do not show in the photograph.)

Toldt [18] pictures (pp. 604-5) the nerves as crossed by both arteries in what proves to be their usual normal relationship. The matter is not mentioned in the context.

Rauber [12] does not mention the relationship, and pictures (pp. 794-5) the artery as superficial but crossing the nerves near their points of superficial emergence, in correspondence with Sappy.

Poirier and Charpy [10] are the only authors of works which I have consulted who make any special comment. They say that the nerve, several millimetres from its emergence, crosses the "middle cerebellar artery," passing sometimes below and sometimes above the vessel. These variations have been noted by Valentine, who has described an anomaly in which the artery passed through the separate bundles of fibres at the point of emergence of the nerves (*cf.* our fig. 3). In their description of the cerebral vessels, however (vol. iii, p. 563), the nerve is both described and pictured as being superficial to the artery.

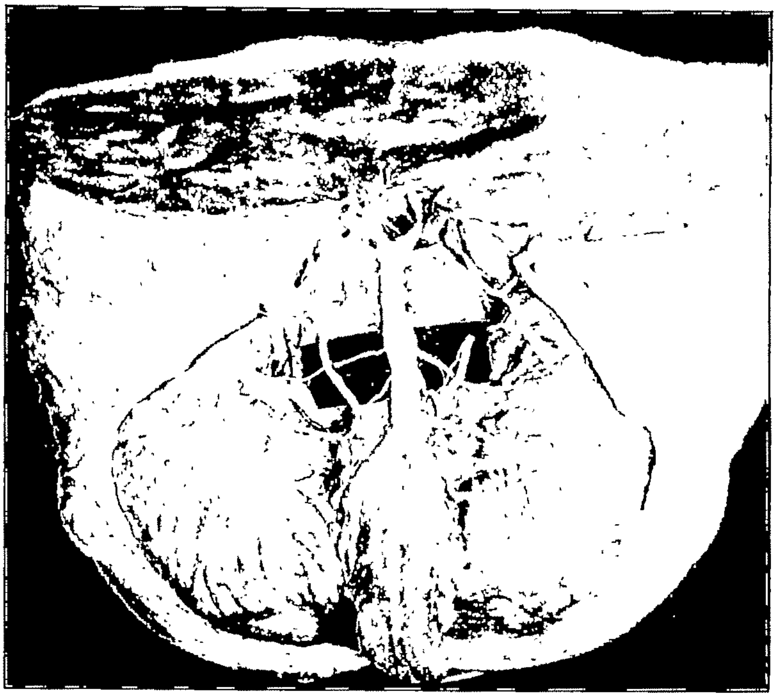

FIG. 3.

No. 7, Table I.—Gumma of pituitary body. No history of diplopia or evidence of ocular weakness on examination. Brain-stem shows no grooving of pons (black paper inserted to secure definition).

Photograph to show anatomical disposition of arteries. The *Aa. cerebelli inf. ant.* cross the abducentes near their points of origin and could hardly compress them. The right *A. auditiva* underlies the nerve; the left pierces it and gives off a small arteriole in passing. With such a disposition of the vessels, therefore "strangulation palsy" could not have occurred.

It can be seen, therefore, that irregularities in distribution may occur, and that, owing to the presumed unimportance of the relationship, it has not been made an especial object of study. Contrary to the conditions pictured in most of the works cited above, one or the other of the arteries lies superficial to the nerves in the large majority of cases, and crosses them a short distance cephalad to their points of emergence.

Looking at the matter purely from an anatomical point of view, in the fifty-six brains that we have examined, thirty of which have been cases of brain tumour, the nerves on both sides have been almost without exception overlain by arteries in such a way that swelling or enlargement of the brain-stem, which would tend to stretch the transversely-disposed arteries, might be expected to produce a constriction of the nerve. Occasionally the arteries have branched off from the basilar so far posterior (as in the diagrams of Sappy and Rauber) as to cross the sixth pair at the level of, or caudad to, their points of emergence (*cf.* fig. 3). Even in these cases, however, the internal auditory arteries, if given off separately, may cross the nerves in such a way as to make strangulation possible. Not uncommonly, as in fig. 2 (right), the nerve may emerge, as pictured by Spalteholz, between the two arteries. In some cases one of the nerves has been found superficial to both arteries, but it is unusual for both nerves to be so disposed. In three cases out of the fifty-nine in our series, the artery has pierced the nerve (as in the anomaly described by Valentine, according to Poirier): in all three instances the anomaly occurred upon the left side (fig. 3).

ABDUCENS PALSIES CORRELATED WITH POSSIBLE ARTERIAL CONSTRICTION.

In the following two tables have been gathered for reference the chief data relating to the neuro-vascular relationship presented by the fifty-nine brains which have been investigated with this point in view.[1] *Table I* includes thirty-nine observations—thirty-three cases of tumour and six of "pseudo-tumour" (four chronic abscesses) in which the

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[1] In these tables, under the heading "Oculomotor Condition" (column 3), is recorded the presence or absence of subjective diplopia during the course of the disease, as elicited by the history, or as present at the time of examination; and also the presence or absence of any observable lack of parallelism of the globes from loss of muscle balance. In the absence of these the condition is noted as "normal."

Under "Anatomical Relationship" (column 5) is recorded the relative position of the arteries and nerves and the presence or absence of grooving. Thus, in *Case I* the *A. cerebelli anterior inferior* crossed the nerve on each side, but there was no grooving of the pons or of the sixth pair by the vessels. As no disturbance of the ocular muscle balance had been observed, the note in column 3 is "normal."

TABLE I.

Case No.	Surgical No.	Oculomotor Condition	Lesion	Anatomical Relationship
1	18,512	Normal	Large right cerebral glioma	Arteries superficial to nerves, but no grooving.
2	18,602	Normal	Small right parietal glioma	Arteries superficial to nerves, but no grooving.
3	18,640	No history of diplopia, but examination shows weakness of right sixth and third	Right cerebello-pontine endothelioma	Arteries removed from specimen: deep pontile grooving, especially on right, which does not affect nerves. Right third compressed between arteries.
4	19,854	Normal (?). (Patient unconscious)	Left frontal glioma	*Right:* artery superficial. *Left:* nerve superficial. Very asymmetrical arrangement; slight grooving.
5	20,296	Normal	Small cerebral tuberculoma; meningitis	Arteries superficial to nerves, but no grooving.
6	20,638	No history of diplopia. (Patient blind and unconscious.) Possible divergent squint	Enormous 400 grm. gliopsammoma, right hemisphere. Hydrocephalus. Diastasis of sutures	Arteries superficial: practically no grooving. Third pair compressed between arteries in much distorted position.
7	21,026	Normal	Pituitary gumma. Arterio-sclerosis	*Right:* nerve superficial. *Left:* artery pierces nerve. No grooving (fig. 3).
8	21,400	Normal	Cerebellar cyst	*Right:* nerve superficial. *Left:* artery superficial. Considerable grooving of pons, escaping sixth pair. Third pair slightly indented by arteries.
9	21,411	History of diplopia	Multiple cerebral melanotic sarcomata	Arteries superficial: right constricts nerve; left caudad to nerve. Moderate grooving
10	21,654	History of periodic diplopia	Gelatinous glioma (?) of uncinate region and lateral recess (right)	Arteries superficial. Deep grooving, especially on right (fig. 1).
11	21,915	No recorded diplopia. (Patient unconscious.) Obvious squint	Cerebellar cyst	*Right:* artery superficial. *Left:* nerve superficial. Deep grooving, which escapes nerves. Third pair kinked and grooved by arteries (fig. 4).
12	22,120	No history of diplopia. Presumable but unrecorded involvement of third and sixth pairs before death	Glioma brain-stem	Arteries superficial: deep grooving, from which abducentes largely escape. Third pair implicated. Nuclear involvement possible (?).
13	22,428	History of diplopia. Convergent squint	Cerebellar tubercle	*Right:* arteries superficial and cut deeply. *Left:* abducens emerges cephalad to *A. cerebelli inf. ant.*, but is overlain and cut by *A. auditiva*. Pons and nerves deeply grooved (fig. 9-13).
14	22,488	Normal	Left temporal endothelioma	Arteries superficial, though asymmetrically disposed. Practically no grooving of pons or nerves.

TABLE I. (*continued.*)

Case No.	Surgical No.	Oculomotor Condition	Lesion	Anatomical Relationship
15	22,551	A transient ptosis with temporary palsy of left third nerve during epileptic attacks	Glioma left hemisphere. Internal hydrocephalus	Arteries superficial, crossing nerves at their points of emergence. Practically no grooving.
16	22,691	Diplopia: left internal squint	Tumour (glioma) compressing side of medulla near foramen. (No increase of tension)	*Right:* abducens involved in tumour. *Left:* artery caudad and superficial: no grooving.
17	22,812	History of recurring diplopia. Bilateral internal strabismus	Right frontal glioma	Arteries symmetrical and superficial to nerves. Deep constriction of left abducens: slight, of right. Third pair compressed between arteries.
18	22,867	Normal	Glioma of temporal lobe	*Right:* nerve superficial. *Left: A. auditiva* superficial, with slight grooving
19	22,896	Normal	Tempero-sphenoidal glioma	Arteries superficial. Slight grooving.
20	23,014	History of diplopia. Convergent strabismus	Glioma of quadrigeminal region	Arteries superficial, with grooving. Possible nuclear involvement (?).
21	22,950	Normal	Glioma temporal lobe and uncinate gyrus	(Right relationship lost in sections.) Left artery perforates nerve. Grooving inconspicuous.
22	23,967	Normal	"Pseudo-tumour." Chronic abscess occipital lobe with pressure symptoms	*Right:* artery superficial. *Left:* artery perforates nerve. No grooving.
23	23,850	Normal	Glioma left hemisphere. Extensive œdema	Arteries superficial with practically no grooving. Very asymmetrical arrangement.
24	24,067	Normal	"Pseudo-tumour." Old abscess left hemisphere	Arteries superficial and symmetrical. No grooving.
25	24,137	No history of diplopia recorded	Uncinate glioma	Arteries superficial and asymmetrical. Considerable grooving: left branches by common trunk crossing near point of emergence.
26	24,307	Normal	"Pseudo-tumour." Old abscess frontal lobe	Arteries superficial, with typical arrangement. No grooving.
27	23,967	Normal	"Pseudo-tumour." Chronic abscess left occipital lobe	*Right:* artery superficial. *Left:* nerve superficial. Considerable grooving.
28	24,357	Normal	"Pseudo-tumour." Hydrocephalus	Nerves superficial. No grooving.
29	24,398	Diplopia. Convergent squint	Cerebellar "neurocytoma" (Mallory)	Arteries superficial and symmetrical. Marked grooving (figs. 6, 7, 8).
30	24,413	History of diplopia	Glioma corpus callosum. Extensive œdema	Arteries superficial; symmetrical, and deeply groove nerves and pons.
31	24,673	Diplopia with divergent squint. (Third nuclear involvement?)	Metastatic carcinoma of cerebrum	Arteries superficial to nerves, but no grooving.

TABLE I. (*continued.*)

Case	Surgical No.	Oculomotor Condition	Lesion	Anatomical Relationship
32	24,714	Normal. Some weakness of conjugate movements to left	Cerebellar glioma ..	*Right :* artery superficial to nerve. *Left:* abducens emerges between *A. cerebelli inferior* and *A. auditiva.* No grooving.
33	25,224	Right abducens palsy with conjugate paralysis	Cystic glioma left lateral recess	*Left:* artery superficial and deeply grooves nerve and pons. *Right :* nerve in tumour (fig. 5).
34	St. Agnes	No history of diplopia. (Homonymous hemianopsia).	Glioma left parietal lobe	Arteries superficial and slightly groove nerves.
35	24,886	Normal	Multiple small metastatic carcinomata; cerebral and cerebellar. (No increase of tension.)	*Right:* artery superficial. *Left:* nerve superficial. Practically no constriction.
36	23,479	Normal	"Pseudo-tumour." Epilepsy	Arteries superficial but no grooving.
37	Church Home	Diplopia. (Nuclear involvement.) Blindness. Divergent squint	Glioma quadrigeminal region	Arteries superficial but no grooving (fig. 2).
38	23,953	History of diplopia. Strabismus variable. (Patient unconscious.)	Cerebellar cyst. Internal hydrocephalus	Arteries superficial. Marked grooving.
39	26,128	No diplopia.. ..	Frontal endothelioma. Extreme pressure	Considerable grooving of pons, especially by vertebrals. Abducentes escape, as nerves emerge caudad to crossing.

TABLE II.

Case No.	Surgical No.	Oculomotor Condition	Lesion	Anatomical Relationship.
40	17,468	Normal	Fracture skull. Intracranial hæmorrhage	Arteries superficial to nerves and symmetrical. No grooving.
41	18,369	Normal. Right conjugate deviation	Cerebral contusion with extravasation over frontal lobes	Arteries superficial and symmetrical. No grooving.
42	18,956	Normal	Internal hydrocephalus. (Infant)	*Right:* artery superficial. *Left:* nerve superficial. No grooving.
43	19,644	Not observed ..	Suppurative meningitis with obstructive hydrocephalus	Arteries superficial and symmetrical. No grooving.
44	20,486	Patient unconscious	Capsular apoplexy ..	Arteries superficial and very sclerotic, but no grooving.
45	21,493	Patient unconscious	Capsular apoplexy ..	Arteries superficial; extensively diseased. No grooving.

TABLE II. (*continued.*)

Case No.	Surgical No.	Oculomotor Condition	Lesion	Anatomical Relationship
46	21,844	Patient unconscious	Tuberculous meningitis. Hydrocephalus	Arteries cross at pontomedullary junction and escape nerves. No grooving.
47	21,942	Normal	Meningitis (Wichselbaun). Hydrocephalus	Arteries superficial but asymmetrical. No grooving.
48	21,980	Normal (?)	Capsular apoplexy ..	Arteries superficial; suggestion of grooving.
49	23,278	Patient unconscious. Conjugate deviation to right	Fracture of base. Intracranial hæmorrhage	Arteries superficial and symmetrical. No grooving.
50	23,370	(Newborn)	Meningitis after forceps delivery with fracture	Arteries superficial and symmetrical. No grooving.
51	23,690	No abnormality observed. Patient unconscious	Apoplexy. Extensive basilar sclerosis	Sclerotic arteries superficial. No grooving of pons or nerves.
52	24,379	No abnormality observed. Patient unconscious	Epilepsy: chronic arachnoiditis	Sclerotic arteries superficial and symmetrical; cross nerves 5 mm. from origin. No grooving.
53	24,203	No abnormality observed	Tuberculous meningitis	Arteries superficial. No grooving.
54	24,290	Normal (?). Conjugate deviation	Encephalitis chronica. Epilepsy	Arteries superficial, but no grooving of nerves or pons.
55	23,398	Patient unconscious. Right conjugate deviation, head and eyes	Encephalitis acuta. Septicæmia	*Right:* artery superficial. (*Left:* relation destroyed.) No grooving.
56	24,307	Normal	Abscess frontal lobe: chronic	Arteries superficial: typical. No grooving.
57	Washington case	Unrecorded.. ..	Microgyria: adiposis dolorosa	Arteries superficial: typical. Suggestion of grooving.
58	Church Home	Unrecorded.. ..	Chronic hydrocephalus	Arteries superficial, with irregular distribution. No grooving.
59	24,337	Normal	Cerebral œdema ..	*Right:* nerve superficial. *Left:* artery superficial. No grooving.

pressure phenomena were identical with those characterizing an actual neoplasm. *Table II* comprises twenty observations on brains with miscellaneous lesions which clinically could not have been mistaken for tumour. Most of them represent acute conditions in which there was no history of diplopia or observable squint, so that they are valuable largely from the standpoint of anatomical relationship, though they show at the same time the rarity of arterial grooving in brains unaffected by the long enduring pressure effects of tumour.

ANALYSIS OF TABLES.

These tables are of interest from three points of view: one concerns the topographical relation of the arteries and nerves; another, the presence or absence of grooving produced by the vessels; the third, the association of recorded diplopia or squint with the presence or absence of grooving.

(1) *Anatomical Relationship.*

It will be seen that in the large majority of the fifty-nine cases the arteries are more or less symmetrically disposed, and overlie the abducentes in such a way as to render constriction possible. In a number of instances, as in Nos. 15, 39, and 46, the arteries cross so far posteriorly as to lie in the ponto-medullary groove (fig. 3, for example), or else so near the points of emergence of the sixth pair as to make it seem unlikely that the nerves could have been affected by the constriction. In other instances the disposition of the vessels was very asymmetrical, and yet one or the other of them, or the combined trunk, crossed the nerve a few millimetres cephalad to its point of emergence.

In no cases were both of the arteries found to underlie the nerves on the two sides, after the fashion usually depicted in the text-books. There were ten cases, however, in which the nerve on one side alone was superficial to the two arteries considered, or to their combined trunk in case they arose from a common stalk: Of these ten cases the right abducens was superficial in three instances (Nos. 8, 18, and 59), and the left in six (Nos. 4, 9, 11, 25, 27, 35, and 42). In three cases the left abducens was perforated—in Nos. 21 and 22 by the *A. cerebelli anterior inferior*, and in No. 7 by the *A. auditiva* (fig. 3), and thus only a single bundle of its fibres could have been constricted. Occasionally, as in Nos. 13 and 32, it was the *A. auditiva* which, on one side at least, overlay the nerve; whereas the *A. cerebelli anterior inferior* crossed the pons caudad to the point of its emergence.[1]

(2) *Arterial "Grooving."*

The most striking feature of the brain-stems of the tumour cases, when once attention has been called to it, is the deep grooving, particularly of the pons, which is produced not only by the branches in which we are chiefly interested, but also by the basilar and its *rami ad pontem* presence or absence of grooving produced by the vessels; the third, the association of recorded diplopia or squint with the presence or absence of grooving.

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[1] From the anatomist's standpoint it would be desirable to examine a larger series of brains than these pathological ones which I have had at my disposal, and particularly injected brains, which would render the investigation of the relationship—provided the tissues were removed with careful preservation of the sixth pair, which are often torn out—much easier than in the case of the bloodless (through perfusion) vessels in my specimens. Aside from the mere demonstration that the topography as usually given is erroneous, the chief value of my tumour material lies in the evidences furnished by these tissues of the deep grooving.

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(fig. 4). The transverse vessels may have cut so deeply into the tissues as actually to lie below the level of the surface. Though difficult to photograph, the grooving is fairly well represented by the shadows, particularly in figs. 4 and 9. It is to be noted that these arteries are not stiffened and sclerosed, but are normal vessels.

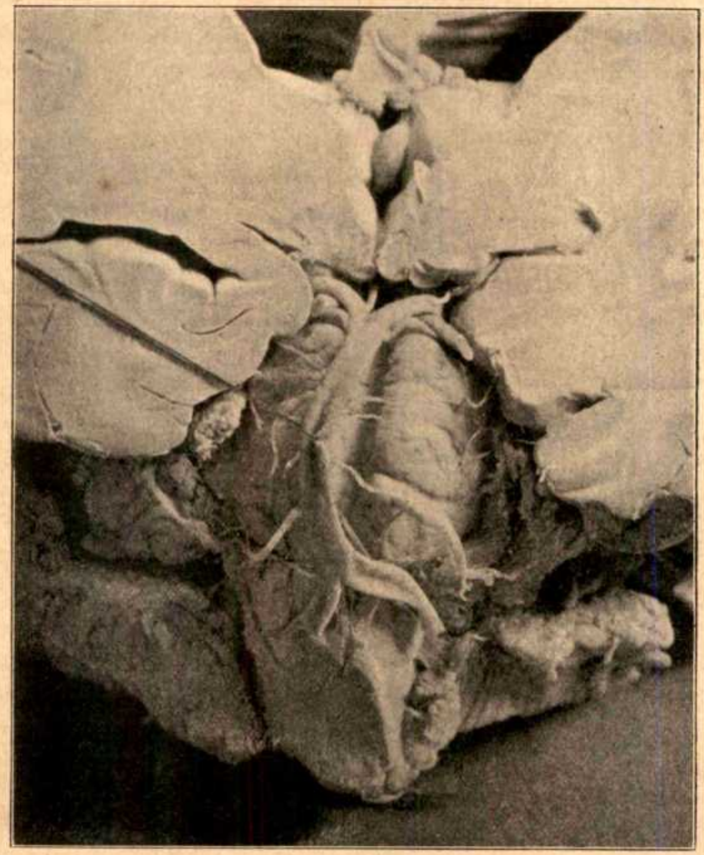

Fig. 4.

No. 11, Table I.—Cerebellar cyst with secondary internal hydrocephalus. Death following lumbar puncture. Patient had a squint affecting third pair and right abducens.

Photograph shows brain-stem with basilar artery lifted from its deep longitudinal groove. All lateral branches also have cut deeply into pons.

Note: (1) Right *A. cerebelli inf. ant.* is superficial to and grooves the abducens.

(2) On the left the abducens is superficial to this artery, which, however, has deeply cut the pons; but it is overlain by the left *A. auditiva int.*, the deep groove made by which can be seen leaving the basilar groove on the right near the medulla.

(It is to be noted that the vessels have been washed free of blood by the fixative agent, and hence are difficult to photograph clearly.)

In the fifty-nine brains, definite grooving was present in twenty-six cases, twenty-five of these being cases of tumour. Inasmuch as the method of hardening and removal of the brains was the same not only for the tumour cases but for the miscellaneous group as well, it is improbable that the vessels could have become sunken into the tissues purely as a result of the method of preparation.

Furthermore, of the eighteen out of the thirty-nine tumour cases which showed no grooving, nearly all were cerebral lesions, and all but one (No. 27) of the "pseudo-tumours" (abscess, hydrocephalus, epilepsy, &c.) fall likewise within this group. Of the twenty-one tumour cases in which grooving occurred, it was pronounced in fifteen, ten of which were subtentorial lesions. Deep grooving occurred, therefore, in only five supratentorial cases (Nos. 17, 25, 27, 30, and 39). Pressure was extreme in all of these cases, and in two of them—cases with excessive vomiting—the cerebellum showed post-mortem obvious signs of œdema. In seven of the twenty-one tumour cases showing grooving it was comparatively slight in degree (Nos. 4, 9, 18, 19, 20, 21, and 34), and in all but one of these cases (No. 20, a glioma of the quadrigeminal region) the lesion was cerebral and more or less remote from the brain-stem. The same is true of the remaining eighteen of the thirty-nine tumour cases in which no grooving was present, the lesions, with only three exceptions, being cerebral and remote. The three exceptions are notable, for one of them (No. 16) was a fibrous tumour compressing the side of the medulla, the patient having never shown any general pressure symptoms other than excessive vomiting; another (No. 35) also showed cerebellar involvement, but there was practically no increase of pressure and no clinically recognizable cerebellar symptoms had been detected; and the third (No. 37) was a glioma of the quadrigeminal region in which pressure symptoms had likewise been inconspicuous—a rapidly progressing lesion with pronounced ataxia and bilateral nuclear blindness and deafness.

In three of the tumour cases (Nos. 12, 20, and 37) there was more or less diffuse oculomotor paralysis, evidently from direct nuclear affection of the third pair at least; but inasmuch as there was no accompanying weakness of the facial muscles, and in view of the obvious grooving, it seems not unlikely that the paralysis of the abducentes in these cases was peripheral and due to vascular constriction rather than to a nuclear involvement. On this view, a strangulation palsy of the sixth pair might be superimposed on a nuclear involvement of the third pair, thus accounting for some of the complex ocular palsies in pontine tumours which affect the *Nn. oculomotorii* and the *Nn. abducentes* without clinical evidence of impairment of the neighbouring nuclei.[1] An illustration of a possible abducens palsy due to constriction on the opposite side to the lesion is shown in fig. 5.

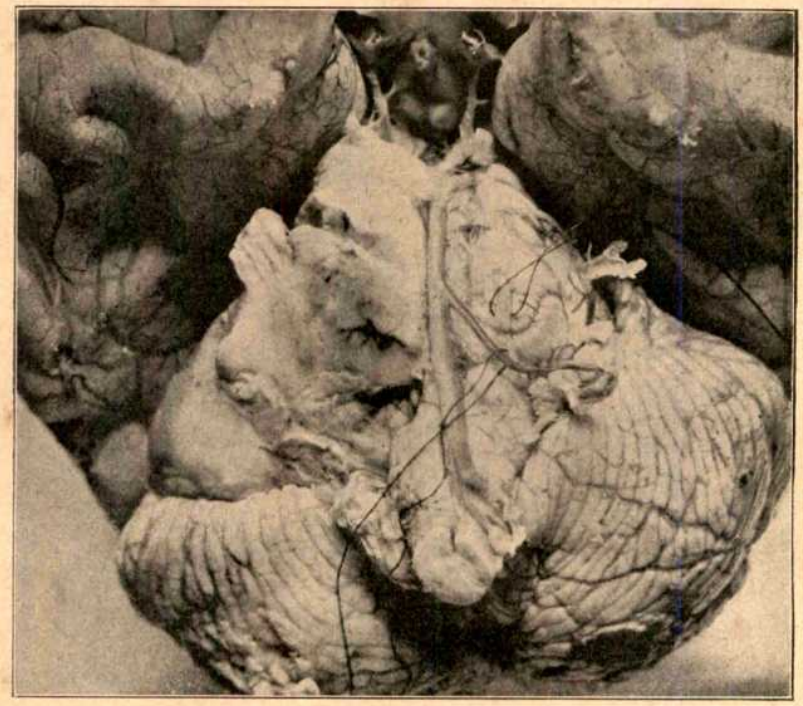

FIG. 5.

No. 33, Table I.—Infiltrating cystic glioma of right lateral recess and pons, with affection of many of the right cerebral nerves (third to tenth) and of the left abducens. Note deep serpentine groove of left side of pons crossing the nerve, made by the artery which has been drawn aside by thread.

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[1] Uhthoff [19] calls attention to the frequent affection of the abducens in cases of pontine tumour, stating that only in 18 per cent. do the nerves escape. It is relatively rare for the abducens to remain the only nerve affected during the further progress of the disease, but it is usually the earliest one to be involved ; and in about half of his cases the lesion was bilateral. In the early stages of a pontine tumour it can long remain an entirely isolated manifestation of the trouble. As the lesion advances, the facial, owing to its nuclear proximity, becomes affected, in 75 per cent. of the cases, but in one-third of these the abducens palsy is bilateral, whereas the facial involvement remains unilateral. It is notable that the trochlear is very rarely involved in these lesions—a nerve which is in such a situation that it cannot easily be implicated, at least by arterial pressure. In the case of tumours in the neighbourhood of the fourth ventricle, Uhthoff notes that associated paralyses of the ocular nerves are very much less common—only four times in sixty-two cases. The abducens, however, is affected in 25 per cent. of lateral recess tumours—more frequently than any other nerve. In more than half of the observed cases the paralysis was bilateral, which would speak in favour of the arterial constriction theory. The third and fourth pair are scarcely ever affected.

Briefly, one may say that the arterial grooving which we are considering is relatively rare in brains not the seat of true tumour, and that when it occurs it is more common in the presence of subtentorial lesions than in those situated in the cerebral hemispheres.

(3) *Relation of Diplopia to Grooving.*

Now, looking at these tables from the standpoint of recorded diplopia or observed squint, it will be seen : (1) That an existent ocular disturbance could not be accounted for on the basis of arterial constriction in only three cases, two of them cerebral (Nos. 31 and 37), both cases of presumed third nuclear involvement and divergent squint, and one a cerebellar case (No. 16), in which there was no grooving ; and the recorded left internal squint remains unaccounted for on any basis. (2) That the ocular disturbance could be best accounted for by arterial constriction in eleven cases, of which nine were cerebellar and two cerebral ; and (3) that an absence of ocular disturbance in the presence of grooving usually indicates either a caudad position of the constricting vessels or else superficially disposed nerves.

Conspicuous grooving such as might well explain an existent convergent squint was present more often in the cerebellar than in the cerebral cases ; and the instances of deep grooving, it may be added, were most often associated with a fixed strabismus, those of slight grooving merely with a history of occasional diplopia.

It is to be noted, furthermore, that only four out of the fourteen subtentorial cases were free from grooving (Nos. 16, 32, 35, and 37). Nos. 16 and 35 were notably free from manifestations of increased tension ; No. 37 was a rapidly growing glioma of the quadrigeminal region, which led early to incapacitating paralyses ; No. 32 therefore remains as the only striking exception. On the other hand, fourteen out of the twenty-five cerebral (supratentorial) cases showed no grooving whatsoever—an indication of the relative freedom from such swelling of the hind-brain as is necessary under these circumstances to produce the form of vascular strangulation under discussion. A certain measure of grooving, it must be added, was present in seven of the cerebral (supratentorial) cases (Nos. 4, 18, 19, 21, 25, 34, and 39) with no clinical record of diplopia. In only two of these (Nos. 25 and 39) was the vascular grooving at all pronounced, and in both cases the abducentes presumably escaped from constriction owing to a caudal position of the vessels. Nevertheless, they may both be regarded as possible exceptions to the rule, for the two factors making diplopia possible through vascular strangulation are present—namely, deep grooving and superficially disposed arteries. In the other five brains the grooving is possibly too slight to have affected the nerves seriously, and Nos. 4, 18, 21, and 34 are explicable on other grounds.

It is natural, of course, that a certain degree of grooving by superficially disposed vessels may not actually suffice to produce weakness of the external rectus at any time in the course of the disease, for doubtless the constriction must be considerable to accomplish this result. When the strangulation is on the border-line of producing functional weakness of the nerves, subjective diplopia, with or without clinically observable squint, may fluctuate in correspondence with varying degrees of tension. All who have a wide experience with these patients are familiar with cases in which periods of extreme headache, leading up to attacks of vomiting, are accompanied by double vision, which disappears

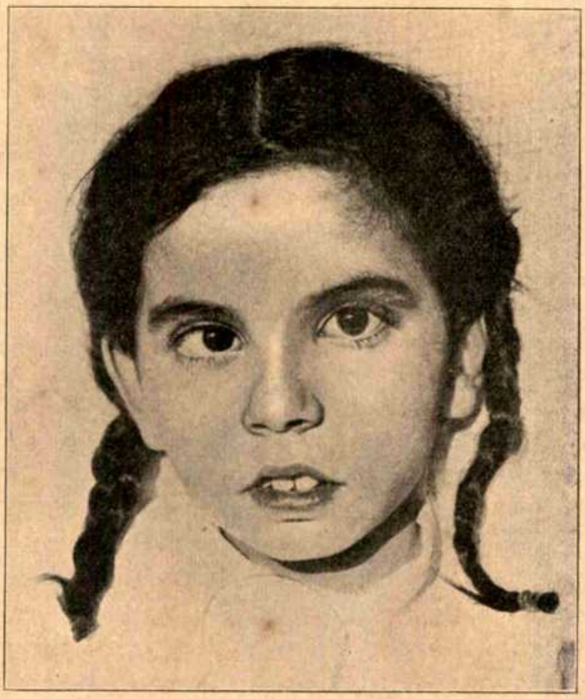

FIG. 6.

No. 29, Table I.—Patient, looking to left, showing double abducens palsy; typical cerebellar symptoms with hydrocephalus which had caused diastasis of sutures.

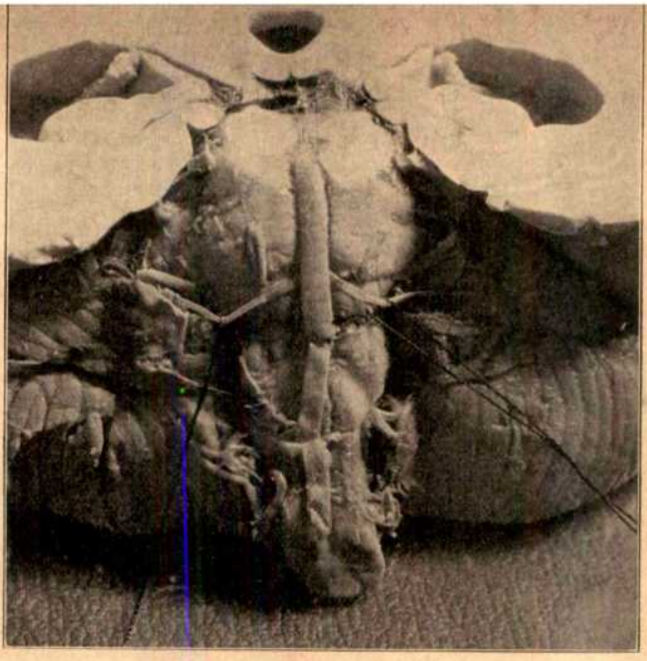

FIG. 7.

No. 29, Table I.—Grooving of both *Nn. abducentes* by symmetrically placed and superficially disposed *Aa. cerebelli inf. ant.*, which give off the *Aa. auditivæ.*

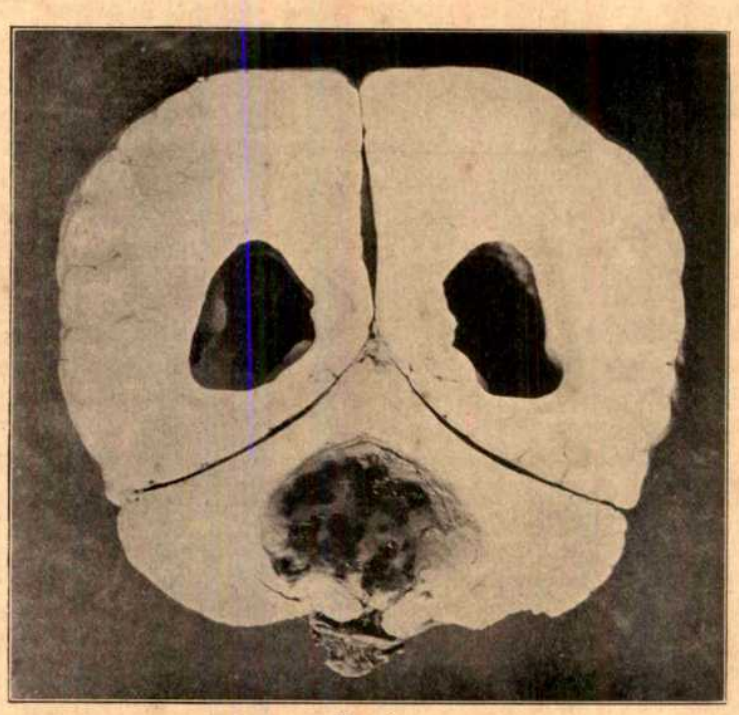

FIG. 8.

No. 29, Table I.—Coronal section posterior to medulla (looking forward) to show mesial tumour, a neurocytoma, not involving motor nuclei.

when the paroxysm subsides. These paroxysms are doubtless due to waves of increased pressure from vascular stasis or neighbourhood œdemas, or varying grades of obstructive hydrops ventriculorum. They are often brought on by some unusual effort, by a change of posture, or, indeed, may occur unaccountably.

One would scarcely expect to find that the clinical history records a bilateral palsy of equal degree, even though, post-mortem, both nerves show evidence of grooving, for the arteries are rarely disposed with such perfect symmetry as shown in fig. 7 ; and even should they be, the constriction on one side or the other might fall short of a total physiological "block" to the transmission of impulses. A functional interruption of this sort, as experimental and clinical observations have taught us, may not necessarily be accompanied by a demonstrable degeneration of nerve fibres. The well-recognized fluctuating type of diplopia, with a periodic convergent squint, may doubtless be attributable to temporary interruptions from this cause, and it is to be noted that normal parallelism of the globes has promptly returned in a number of cases after a successful decompression. Doubtless, when the constriction is extreme and of long standing (as in No. 13), permanent organic changes in the nerve will occur. The following cases may serve as examples to illustrate some of these matters in greater detail :—

Case No. 29 (Surgical No. 24,398).—*Median cerebellar tumour with double convergent squint. Symmetrically disposed vessels producing bilateral grooving of both abducentes. No degeneration.*

The patient, a child aged 9, admitted July 9, 1909 ; had fallen, producing a frontal scalp wound five years before admission. History otherwise unimportant.

Present symptoms observed for six months : frontal headaches, staggering gait, and rolling of head ; recurrent projectile vomiting. Owing to static ataxia has been unable to stand or walk for the past three months. Child has been "cross-eyed" for several weeks (fig. 6).

Examination.—Apparent diastasis of cranial sutures. "Cracked pot" sound on percussion. (Internal hydrocephalus?) Dilatation of extracranial veins. Slight exophthalmos. Suboccipital tenderness.

Cranial Nerves.—Anosmia : 7 D. of choked disc with loss of visual acuity to $\frac{1}{100}$ and colour interlacing, though but slight constriction of fields ; bilateral convergent squint ; weakness of left seventh ; impairment of right eighth, with tinnitus ; otherwise negative.

Cerebral lobes.—Negative in all respects, except for slight mental inactivity and forgetfulness.

Hind-brain.—Pronounced ataxia of extremities, particularly on the left ;

inability to assume and hold upright position standing or sitting. Nystagmus in all directions.

Diagnosis.—Intracerebellar tumour.

Operation.—July 13, 1909. Exposure of a median, well-encapsulated cerebellar tumour. Case difficult, owing to extreme tension and unsatisfactory primary evacuation of cerebrospinal fluid. On account of the extensive protrusion an attempt to enucleate was forced on the operator at this stage. Removal only partially accomplished before medullary symptoms set in. Closure of wound. Death three hours later, with hyperpyrexia.

Autopsy.—Brain hardened *in situ* as usual. Grooving of abducentes (fig. 7). The tumour (pronounced a neurocytoma by Dr. F. B. Mallory) occupied a median position in cerebellum (fig. 8) extending upward towards the vermis. Nuclear region in floor of the fourth ventricle is free from gross lesion, but might have suffered from compression, though tumour lies posterior and remote.

Careful histological study of the sixth pair shows fairly deep grooving, but no degenerated fibres on either side of the constriction are demonstrable. Constricting vessels normal.

Case No. 13 (Surgical No. 22,428).—*Multiple tuberculomata. Ocular palsies without direct nuclear involvement. Deep bilateral abducens strangulation by A. auditiva interna, with extensive degeneration.*

The patient, a man 29 years of age, admitted to Dr. Barker's service, May 9, 1908, with pleurisy and laryngitis, recognized for some months as tuberculous. Pyrexia and loss of weight.

Intracranial Symptoms.—Indefinite headache for the past month. At present, intense posterior headaches with vomiting and choked disc. Subjective numbness in right face and fingers. Weakness of the lower right face. Diplopia, with obvious lack of parallelism in globes and weakness of conjugate movements (pupils equal and reactions normal). Otherwise practically nothing. Complete absence of evidences of cerebellar lesion other than occipital headache and some resistance to movements of neck.

Diagnosis.—Intracranial tuberculosis ; character uncertain.

A rapid advance in pressure symptoms, with prostrating headaches, made it seem advisable to attempt a decompression, though the seat and nature of the lesion remained obscure.

Operation. — May 22, 1909. Attempted subtemporal decompression. Anæsthetic badly taken ; cyanosis. Extreme tension of dura. Though aware of the risk, attempt was made to diminish tension by lumbar puncture, a cerebellar lesion not being suspected. Fluid under great tension ; sudden cessation of flow after 7 c.c. withdrawn. Immediate respiratory failure. Temporary resumption of spontaneous breathing after opening dura at established subtemporal bone defect. Secondary cessation. Death after several hours of artificial respiration.

Autopsy.—Brain hardened in the usual fashion. Extreme foraminal protrusion of cerebellum and medulla (fig. 9). Basilar vessels normal, but deeply groove the pons. Constriction of both abducentes extreme; third pair also deeply indented by closely placed posterior cerebral and anterior cerebellar branches. On section brain shows multiple solitary tuberculomas; one fairly large growth (2 cm. in diameter) situated in left cerebellum; extensive cerebral and cerebellar œdema. Nuclear region in floor of the fourth ventricle free from gross lesion.

A histological examination of the nerves by Dr. Charles M. Byrnes shows an extensive degeneration of fibres on both sides of the constriction, at which point destruction and replacement by scar tissue has been extensive. The marked constrictions produced by the arteries is well shown in figs. 10 and 12, and the degenerations in figs. 11 and 13. The vessels are normal.

In the hope that some clinical relationship might be established between a recorded diplopia (particularly when due to a convergent squint) and the situation of the lesion, a cursory review has been made of the histories of eighty-one cases of brain tumour—cases in which the lesions have been either demonstrated or removed at operation, or, in the presence of an unlocalizable lesion, cases in which a simple decompression has been performed. Stress cannot be laid upon the exactness of the figures, for there are many possible sources of error; thus, though subjective diplopia may have been recorded in the anamnesis, the patient may not have understood the meaning of "double vision," or it may not have been inquired into; the "distant" symptom of oculomotor palsy is late in occurrence, and many patients were decompressed at an early stage; confusing oculomotor palsies, central or peripheral, may have been present in combination with an abducens weakness; the diplopia in some cases, as in the hypophysial lesions, was obviously not due to a strangulation palsy, and so on. Nevertheless, in some respects the figures are not uninteresting in connexion with the cases included in Table I, in which the arterio-vascular relationship was demonstrable after death.

Of the eighty-one cases, fifty-four represent cerebral, or presumably cerebral, and twenty-seven cerebellar, or presumably cerebellar, lesions. Nineteen, or 75 per cent., of the subtentorial (cerebellar and pontine) cases showed a positive squint on examination or gave a definite history of periods of diplopia. Eight, or only 15 per cent., of the cerebral cases gave such a history or showed squint, and in all but three of these the condition can be attributed to a direct peripheral involvement of the nerves in a basilar growth which had led to multiple palsies. One would naturally expect that the subtentorial lesions would be more likely to produce diplopia from direct nuclear involvement (as in the pontine tumours,

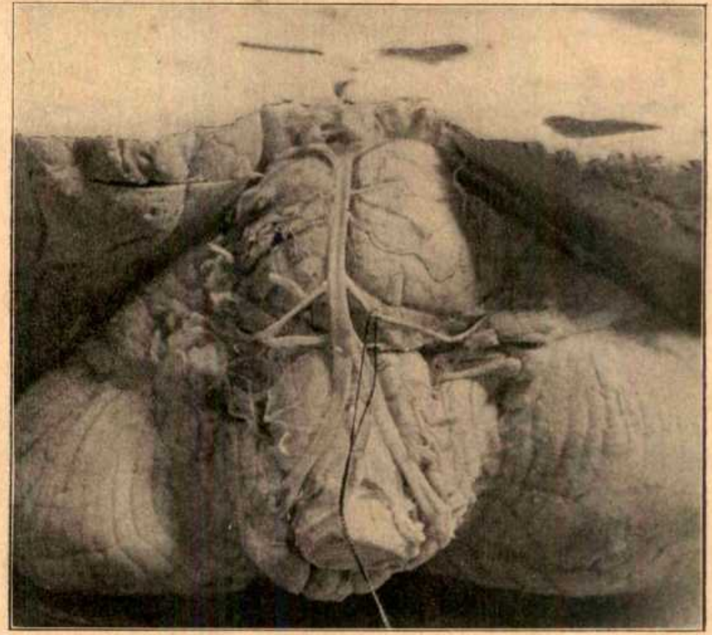

FIG. 9.

No. 13, Table I.—Tuberculoma of left cerebellar hemisphere and multiple tuberculomas of cerebrum with œdema and greatly increased tension. Fluctuating palsies of the sixth pair. Marked foraminal herniation.

Note: (1) Pons much grooved by all vessels, and even the abducens themselves have left imprints (*cf.* on right where nerve is turned out of bed).

(2) On the left the two arteries arise from a single trunk which is superficial to the abducens and has deeply cut into pons and across the nerve (artery held away by black thread).

(3) The right abducens is also crossed and constricted by both *A. auditiva int.* and *A. cerebelli inf. ant.*, which crosses the nerve just caudad to the ponto-medullary groove (*cf.* figs. 10-13).

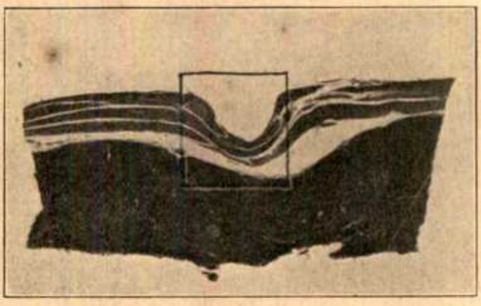

FIG. 10.

No. 13.—Longitudinal section of *N. abducens sinistra* showing imprint of *A. cerebelli ant. inf.* Squared area enlarged in fig. 11. Hæmatoxylin and eosin stain (*cf.* fig. 9).

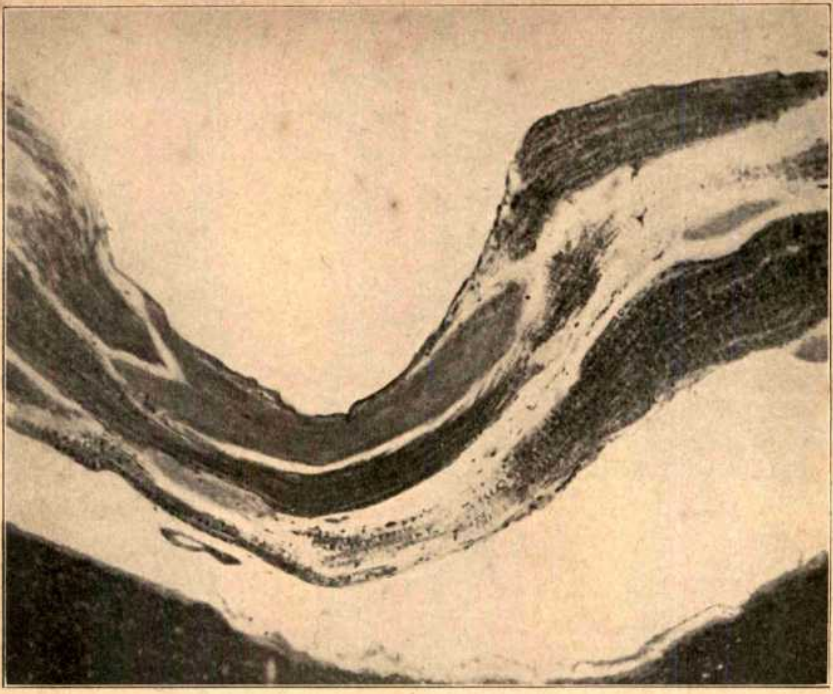

FIG. 11.

No. 13.—Enlargement of area squared in fig. 10 to show cicatrization of bundle which lay in juxtaposition to artery and much degeneration of fibres of other bundles. Weigert stain; yellow areas screened out from negative.

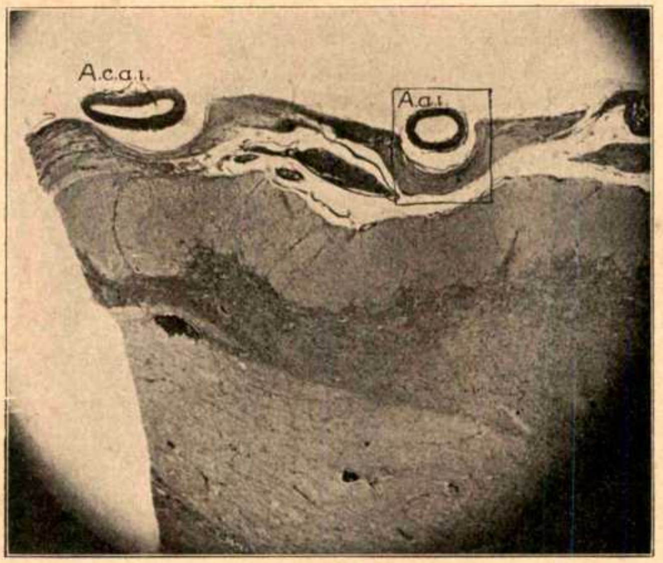

FIG. 12.

No. 13.—Longitudinal section of *N. abducens dextra* showing transverse indentation made by *A. cerebelli ant. inf.* (A.c.a.i.) and by *A. auditiva int.* (A.a.i.) (*cf.* fig. 9). Squared area represents enlarged field in fig. 12. Hæmatoxylin and eosin stain.

of which there were four instances), or from direct peripheral affection due to pressure of a cerebello-pontine endothelioma, of which there have been six examples. In nine of the nineteen cerebellar cases the squint disappeared after the operation, together with the subjective diplopia. Some of these cases represented simple suboccipital decompression; in others the growth was removed, and it is unlikely that this could have been accomplished without permanent damage to nerve or centres if they had previously suffered from an actual "neighbourhood" lesion rather than from some "distant" or secondary process.

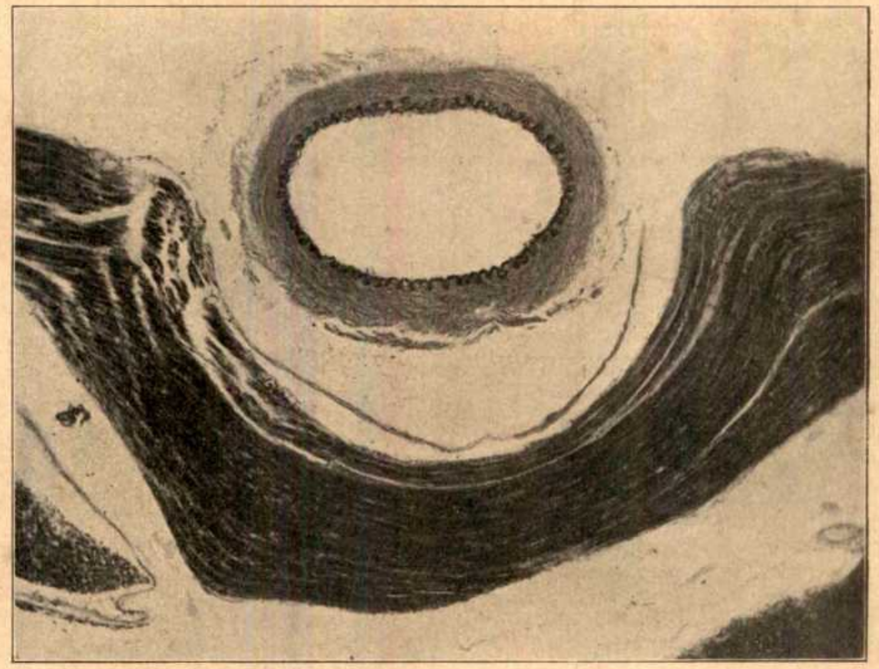

FIG. 13.

No. 13.—Enlargement of area squared in fig. 12 to show degenerated fibres and normal arterial wall. Weigert stain: yellow areas screened out in photograph.

IN SUMMARY.

It seems fair to say, therefore, (1) that in the usual topographical relationship the arteries are superficial and cross the nerves in such a way as to render constriction possible; (2) that in the majority of the fatal cases in which diplopia (particularly in association with a conjugate strabismus) had been recorded, the pons was grooved and the abducentes constricted by the arteries; (3) that these symptoms were much more common in the cerebellar cases, though not alone restricted to them; (4) that the cerebellar lesion, though often so remote as to render unlikely any possible direct affection of the nerves themselves or of their centres, nevertheless, owing presumably to swelling and enlargement of the hind-brain, produced such a stretching of the arteries around the brain-stem as to constrict and groove the nervous tissues, much as though a rubber band had been placed around them; (5) that in cases of extreme constriction the nerves may be found degenerated and replaced by scar-tissue at the point of constriction; and, finally, (6) that the "distant" symptom of a convergent squint may disappear after the successful removal of a cerebellar tumour whose situation was too remote to have directly affected the peripheral neurones of the sixth pair.

If, on this basis, abducens palsies may in some cases be attributable to arterial constriction, they may in a sense be regarded as one of the general manifestations of pressure or tension; a convergent squint, furthermore, like each of the other so-called general pressure symptoms, may have a certain localizing value as speaking in favour of a lesion of the hind-brain.

ABDUCENS PALSIES IN OTHER STATES.

It is well known that in many conditions besides tumour the sixth pair exhibit a particular susceptibility to injury. This is the case in fracture of the cranial base, in otitis media, cerebral arterio-sclerosis, hydrocephalus, and the like.[1] Köllner [7] has recently made a study of 250 cases of abducens palsies occurring either alone or in combination with lesions of the other ocular nerves. There were 13 instances with tumor cerebri, 13 following trauma, 70 with tabes, and 40 with lues; the rest were due to more or less scattered lesions. Doubtless, in the large majority of the syphilitic cases, the nerve was directly involved in a gummatous meningitis. However, judging from the fact that in none of Köllner's series was the diagnosis confirmed by a subsequent section, it is not improbable that a number of the cases classified as lues were more properly tumours. This at least would conform with our experience with the clinical diagnosis of intracranial lues. In eight of the 13 supposed tumour cases the oculo-motorius was involved, in company with the abducens.

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[1] A number of the conditions apt to be associated with paralysis of the sixth pair are cited at length by Ricaldoni [13].

Uhthoff [19] has given some statistics of the ocular disturbances accompanying hydrocephalus and meningitis serosa. A convergent strabismus was by far the most common symptom occurring in 26 cases in his series, of which number nine came to autopsy. A direct nuclear affection was demonstrable in only one case, the paralyses in the others being regarded as a form of pressure palsy to which the abducens is susceptible "owing to its long intracranial course." A combination of abducens and other palsies was relatively rare in these cases. The author speaks of the occasional subsidence of the ocular disturbances after the withdrawal of the fluid by a lumbar puncture.

An unaccountable paralysis of the abducens—the so-called *Syndrome Gradenigo*—has been observed as a complication of otitis media without abscess or other demonstrable cerebral lesion. I have seen several instances of this combination, in each of which the lesion was attributed to a cerebral œdema, for all of the patients showed headache, vomiting, and a low grade of choked disc. These œdemas are presumably akin to the meningitis serosa of Quincke, and in most of our cases a lumbar puncture or a subtemporal decompression has not only largely relieved the pressure symptoms, but has led to a rapid subsidence of the diplopia. The fluid in all of these cases has been sterile. It is not improbable, therefore, that disturbances of this kind may be ascribed to some swelling and œdema of the brain-stem which had brought about the same constricting effect on the part of the cerebellar arteries that we have described as existing in cases of brain tumour.

A similar explanation may account for the mysterious abducens palsies which occasionally appear a few days after the subarachnoid injection of stovaine,[1] for the profound headache which so often follows this procedure is quite possibly due to an œdema of the brain-stem. On a similar basis—namely, of transient œdemas—one is tempted to speculate on the recurrent diplopias which accompany certain ophthalmic types of recurring migraine, though it must be acknowledged that the oculomotor lesion involving either the third or sixth nerve is, like the headache, usually, though not always, confined to one side. A collection of thirty-six of these cases was made by Spicer and Ormerod [17] in 1896, and, hesitating to accept the usual functional interpretation of the symptom, they were inclined to ascribe it to some organic lesion.

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[1] The subject is fully reviewed in a recent paper by Wendell Reber.

ARTERIAL CONSTRICTION OF OTHER CRANIAL NERVES.

It is well known that nerves may be rendered incapable of transmitting impulses—"blocked," in other words—by relatively slight grades of constriction not necessarily sufficient to produce degenerative changes. It is well known, too, that the ocular palsies occurring in cases of brain tumour may be more or less fluctuating in their intensity—a condition of things easily accounted for on the basis of an arterial constriction which varies in degree from time to time.

A form of vascular indentation affecting the third pair has been observed in a number of the brains in our collection, many of them representing cases in which paralyses of the *Nn. oculomotorii* have proven to be "false localizing signs." It can be seen in fig. 4 that the *A. cerebelli superior* and the *A. cerebri posterior* may lie in close proximity to one another rather than at a distance, as appears in fig. 2. Inasmuch as the third nerve emerges between these two vessels it could easily become kinked or deeply indented by closely opposed arteries, particularly should any considerable change of position in the brain-stem be accompanied by such an increase in size of the subtentorial structures as would tend to put these vessels on the stretch. Though our observations on this point have been less thorough than those regarding constriction of the sixth pair, we nevertheless have encountered a number of striking illustrations. The condition is well shown in the photograph of the brain-stem of Case No. 11 (fig. 4).

In speaking of the general effects of pressure exerted on the brain and cerebral nerves by a tumour, Bruns [2] refers to the possibility that paralyses may be due, not only to direct involvement in or pressure by a growth or gumma, but also to the dislocation (Verschiebungen) of the brain itself. He quotes Wernicke, to the effect that a basal tumour on one side can dislocate the brain in such a way as to cause paralyses of the contralateral cerebral nerves, which become pressed against the sharp dural borders of their foramina of emergence, the nerves on the side of the tumour being greatly stretched at the same time. He says further:—

> "Schliesslich, darauf hat Wernicke besonders hingewiesen, können durch Verschiebung der Hirnmassen Gefässe, die einen Hirnnerven umspannen, an denselben angedrückt werden und ihn schliesslich direkt durchschneiden; das ist am Olfactorius, am Tractus und Nervus opticus, am Oculomotorius und Abducens durch die entsprechenden Gefässe beobachtet—neben der Verschie-

bung der Hirnteile spielt hier allerdings wohl auch die Spannung durch den Hydrops ventriculorum eine grosse Rolle."[1]

In view of this concise statement it is possible that the association of palsies and vascular constriction is a matter of more common knowledge than I had supposed, though I have failed to find any definite note in regard to the particular form of strangulation of the abducentes which has been gone into so fully.

Instances of arterial grooving of other nerves have been given by a number of writers. Thus, Theodore Sachs [14] pointed out that a factor, at least in the optic atrophy, so often associated with a tumour of the pituitary body, may be an indentation of the optic tracts where they are crossed by the externally placed carotid or its anterior cerebral branches, his view being that the slowly-enlarging growth situated within the confined space of the chiasma pushes the nerves against the resistant vessels, which do the damage rather than the bony walls of the chamber. He pictures very clearly such a transverse grooving of the optic nerves, and has made studies of the resultant degenerations. It, however, does not appear to be a condition of such rarity as Sachs was led to believe, for the illustration accompanying his article might well serve to depict precisely the same vascular indentation observed in two of our own cases of hypophysial tumour with optic atrophy. Indeed, Sachs was not the first to make this observation, for Türck had called attention to a similar case forty years before, and Leber had pointed out that the constriction was presumably due to the fact that the tumour had put the vessels under tension, so that the intervening soft nerve-substance had suffered in consequence.

On similar grounds, Oppenheim [8] has accounted for the unusual homolateral hemiparesis and hemianalgesia observed in a case of cerebello-pontine tumour; for he found, post-mortem, that the vertebral artery on the opposite side to the lesion lay tightly stretched across the pons at the bottom of a deep groove, which suggested the likelihood of an interference with conduction from this cause rather than from pressure of the structures against the cranial base, or from stretching of the fibres. Doubtless many other similar examples of vascular constriction could be found.

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[1] I have failed to trace in Wernicke's writings the original source of this statement for which Bruns gives no reference. There is an article by Otto Wernicke, of Buenos Ayres ("Ueber Lähmung der Seitwärtswender," *Arch. f. Augenh.*, 1900, xli, s. 188), describing the occurrence as rare of a double abducens palsy in a case of multiple tuberculoma seen in the clinic of Robert Wernicke. One of the lesions occupied the pons, and to this the ocular symptoms were accredited. The author acknowledges difficulty in accounting for the absence of a bilateral facial palsy, and does not believe that the usual explanation of the greater resistance of the seventh nuclei to pressure really solves the question.

Though it is desirable to lay emphasis on the cerebral nerve constrictions which may be produced by normal vessels, a word may be said in regard to the neighbourhood paralyses produced by basilar vessels tortuous and stiffened from disease. For obvious reasons these lesions have been more commonly observed than the constrictions by normal vessels, for with the former it requires no intracranial fixation of the tissues to set the lesion so that it is apparent after removal of the encephalon. Owing to the primary importance of the optic nerves and the detailed studies made by ophthalmologists in seeking for the causes of visual disturbance, we are especially familiar with the pressure effects of atheromatous vessels in the neighbourhood of the chiasma.

In his monograph on the subject, Otto [9] reported a number of instances emphasizing the mechanical effect of the dilated and stiffened vessels in pressing the nerves against some resistant structure like the optic foramen [21], and cases are recorded [1] of almost complete division of the nerve from the pressure of a sclerosed ophthalmic artery.

Similar affection of other of the cerebral nerves may readily be produced by the juxtaposition of an extensively diseased and stiffened artery. The symptoms, however, in most cases of pronounced cerebral arterio-sclerosis represent such diffuse changes on the part of the cerebrum as a whole that the possible pressure palsies of individual nerves are less clear and naturally less frequently investigated than is the case with the opticus. There are a number of brains in our series showing one or another of the cerebral nerves in dangerous proximity to atheromatous arteries, but in none of them has there been any grooving of the brain-stem by the arterio-sclerotic vessels comparable in any way to the constriction produced by normal arteries in the tumour cases. In the brains of our collection (cf. Table II.) even when the basilar, the vertebrals and their several branches, show extensive disease, the vessels, though stiffened and tortuous, usually (though not always) lie free from the pons without leaving their imprint on the nerve structures.

Thus it would seem that some enlargement of the subtentorial structures, due to a growth or to œdema which has tended to put upon the stretch the normal arteries encircling the brain-stem, is the chief element in producing the form of vascular strangulation most likely to affect the function of the sixth pair.

CONCLUSIONS.

The usual conjectures offered in explanation of the common occurrence of an internal squint in cases of brain tumour are not entirely satisfactory, and the view is submitted that in certain cases the condition may be due to strangulation by transverse branches of the basilar artery.

This view is supported by the findings (1) that the arteries, contrary to the usual anatomical description, generally overlie the nerves; (2) that in a series of brains of tumour cases the vessels which normally encircle the brain-stem often produce a more or less deep grooving of the nervous tissues; (3) that the abducentes in many of these cases are deeply constricted; and (4) that a large percentage of the clinical histories of cases which show post-mortem a pontine grooving, with accompanying implication of the nerves, record either subjective diplopia or the actual presence of a convergent squint observed during life.

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TUMOURS OF THE THIRD VENTRICLE, WITH THE ESTABLISHMENT OF A SYMPTOM-COMPLEX.

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IN a careful *résumé* of the literature the writer was struck with the lack of accurate knowledge regarding the diagnosis of tumours in the third ventricle, for, curiously enough, no attempt has been made to collect and analyse the cases bearing upon this subject. Within a few years I have seen three cases of tumour of the third ventricle, and was impressed with the possibility of making a correct diagnosis at least in some of the cases, and with this idea in view have studied all those with necropsy which could be found in the literature. Altogether I have collected twenty-seven, which, with my own, make thirty. It is, of course, probable that some have been overlooked.

These cases have been limited entirely to tumours which grew from the choroid plexus or the ependymal walls, and those which extended into the third ventricle from the surrounding structures have been excluded as well as those in which the hypophysis was involved.

Most are, clinically, of not much import, as few were well studied. In many only the post-mortem findings were given, while the cases in which both the clinical and pathological reports were complete are rare indeed.

REMARKS.

The third ventricle in life contains cerebrospinal fluid and part of the choroid plexus. Most of the cerebrospinal fluid is secreted by the choroid plexus of the lateral ventricles, and the natural flow is from the lateral to the third and from the third to the fourth ventricle by means of the aqueduct of Sylvius, and then to the subarachnoid space through the foramen of Magendie. Any lesion, therefore, of the third ventricle is liable physically to interfere with the normal flow of the fluid. Manifestly, a small tumour situated in the floor of the ventricle and not interfering either with the foramina of Monro or the aqueduct of Sylvius may not cause much obstruction, whereas a tumour so situated as to hinder either of these communications will promptly cause symptoms.

A tumour, no matter how situated, unless of small size, must cause pressure on the choroid plexus, and therefore interfere with its normal function. This in some way causes over-accumulation of fluid. According to Mott, in larger tumours it may be partially due to pressure on the veins of Galen, which interferes with the venous return from the choroid plexus and thereby causes not only accumulation of cerebrospinal fluid in the ventricles, but also serous exudation. In other words, in lesions of the third ventricle an internal hydrocephalus will necessarily be produced. This is borne out by the study of the cases in the literature, for of these, internal hydrocephalus was present in every case with the exception of three, in which it was not mentioned, but in which the observations may not have been made.

Ordinarily, in an acquired internal hydrocephalus all the ventricles are equally dilated, but it can be readily seen that in such instances as in Case 3 (Weisenburg), in which there was direct obstruction of the foramina of Monro, there may be predominant dilatation of the lateral ventricles with only little of the third.

The more direct group of symptoms which result from lesions of the third ventricle depend upon pressure on the surrounding structures. The third ventricle is surrounded on either side by the optic thalami, inferiorly by the optic chiasma and pituitary body, and superiorly by the velum interpositum which transmits the veins of Galen. Its outlets are the foramina of Monro and the aqueduct of Sylvius. When there is encroachment upon its space the increase in pressure which results is transmitted along the lines of least resistance to the other cavities through the foramina of Monro and aqueduct of Sylvius, rather than to the structures which offer solid resistance, such as the thalamus.

It is necessary, before discussing symptoms more specifically, to consider the characteristics of growths which occur in the third ventricle. As has already been mentioned, those tumours only were considered which grew either from the choroid plexus or from the ventricular walls. Their nature varied considerably, but had no direct bearing upon the symptoms, which depended entirely upon their size and situation. Manifestly a tumour of small size situated in the floor of the ventricle

Reported by	General Symptoms	Ocular Symptoms	Inco-ordination	Mental Symptoms	Other Symptoms	Post-mortem Findings
Barié. Referred to by Schuster, Paul, "Psychische Ströungen bei Hirntumoren." Stuttgart, 1902, S. 168. (Unable to obtain original reference.) Woman, aged 56	Not mentioned	Not mentioned	Not mentioned	Stupidity	Paresis and anæsthesia of both extremities	Glioma of third ventricle.
Bielchowsky, Max. *Deut. Zeitschrift f. Nervenheilk.*, 1902, Bd. xxii, S. 54. Girl, aged 18	Headache, vomiting, choked disc	Paralysis of associated ocular movement and of convergence upward and downward, lateral movements being also impaired; left pupil larger than right, both pupillary reactions lost, diplopia	Cerebellar inco-ordination	Tendency to somnolence	Disturbance of hearing, slow speech, weakness in right side, increased knee-jerks	Epithelial tumour growing from the choroid plexus in the third ventricle extending into the aqueduct of Sylvius and bisecting the parts anteriorly in the cerebral peduncles compressing and pushing apart the red nuclei, compressing the left foot and the anterior and posterior corpora quadrigemina, also both pulvinars. Most of the cells of the third nuclei were destroyed. Dilatation of all the ventricles.
Birch-Hirschfeld. "Lehrbuch," 1st half, 1897, p. 230	No clinical history	.. ..	.. ..	.. .. ..	.. .. ..	Papilloma floor of third ventricle.
Bollinger, O. *Münchener med. Wochenschr.*, 1887, Bd. xxxiv, S. 789. Woman, aged 26	Recurrent headache, dizzy attacks and vomiting, choked disc	Paresis of left sixth ..	Not mentioned	Slow apathetic mentality, unconscious attacks	Not mentioned ..	Primary actino-mycosis growing from the ependymal walls of the third ventricle, compressing the optic thalamus and anteriorly the fornix and septum pallucidum. Dilatation of the ventricles.
Bristowe, J. S. *Brain*, 1888, p. 182. Boy, aged 4.	Optic neuritis, congestion of the veins in the upper eyelids	Diplopia	Not mentioned, although diagnosis was made of cerebellar tumour	Drowsiness ..	Symptoms began with tremor and loss of power in left limbs followed by similar condition in right	Tubercular mass in third ventricle involving both thalami, followed by tubercular meningitis. Small tubercular mass found on internal surface of left occipital lobe. Dilatation of lateral ventricles.
Calonzi, A. *Il Policlinico*, 1908, vol. xv, p. 130. Boy, aged 12	Headache, nausea, vomiting, vertigo, choked disc	Paresis of associated upward ocular movement and of both external recti	Cerebellar gait	Not mentioned ..	Reflexes normal	Cystic tumour growing from the choroid plexus, extending to the pituitary body and into the aqueduct of Sylvius. Dilatation of lateral ventricles.

Cor , and Ranvier, L. "Manual of Pathological Histology," 1880, Phila., Trans., vol. i, p. 878.	No clinical history appended					Papilloma growing from the ependyma of the third ventricle, projecting into the lateral ventricles through the foramen of Monro.
Falkson, R. *Virchow's Archiv.*, 1879, Bd. lxxv, S. 550. Boy, aged 16	Failing vision, no choked disc	Diplopia	Not mentioned	Stupidity, loss of memory	Not mentioned ..	Chondro-cysto-sarcoma growing from ependymal walls.
Finkelnburg, R. *Deut. Zeitschrift f. Nervenheilk.*, 1902, Bd. xxi, S. 460	Headache, choked disc, nausea, vomiting, vertigo. Disappearance for six months with recurrence	Right pupil larger than left with prompt reactions, paresis of external muscles of right third with the exception of levator, and of right fourth and both sixth. These symptoms almost disappeared for six months with sudden recurrence of irregular pupils and impaired reactions, bilateral ptosis, weakness of all the muscles of both thirds	Cerebellar gait	Dull, apathetic, tendency to somnolence	Weakness of left lower seventh and twelfth and of left limbs with increased reflexes, this almost disappearing for six months and then reappearing	Cystic glioma of the third ventricle affecting right thalamus, tumour extending into the aqueduct of Sylvius and compressing the anterior corpora quadrigemina and posterior part of the peduncle and pons. Dilatation of lateral ventricles. No microscopic examination of brain.
Dutkin, Esther. *Freiburg i/B.*, 1905, I. D. (Unable to obtain original.) Boy, aged 16	Periodic headache and vomiting, later disturbance of vision and optic atrophy	Not mentioned	Not mentioned	Normal	Reflexes increased	Cholesteatoma in third ventricle. Internal hydrocephalus.
Henneberg, R. *Charité Annalen*, 1902, Bd. xxvii, S. 516. Case 2. Man, aged 50	Headache, margins of discs blurred	Left pupil larger than right, lost reactions	Normal ..	Dementia ..	Tongue deviated to the left, reflexes normal	Papilloma growing from the choroid plexus of the third ventricle, extending into the aqueduct of Sylvius which was much dilated. The tumour grew in the midline and separated the red nuclei, compressing them as well as the anterior corpora quadrigemina. In the left third nuclei was a fresh hæmorrhage and the ganglion cells were diseased. The lateral ventricles were only slightly dilated.

Reported by	General Symptoms	Ocular Symptoms	Inco-ordination	Mental Symptoms	Other Symptoms	Post-mortem Findings
Kauffman, O. J. *Birmingham Medical Review*, 1905, p. 231. Man, aged 50	Headache and dizziness	Blindness from birth ..	Not mentioned	Not mentioned ..	Not mentioned ..	Myxosarcoma of third ventricle.
Meyer, E. *Archiv. f. Psychiatrie u. Nervenkrankheiten*, 1899, Bd. xxxii, S. 320. Man, aged 58	Headache, vertigo, vomiting, later optic neuritis	Reaction of left pupil diminished	Cerebellar gait. Tendency to fall backward and to the right	Loss of memory and orientation of time and place, false reminiscences and fabrications, resembling Korsakoff's psychosis	Limbs weak, left more than right. Knee-jerks increased	Sarcomatous tumour of the third ventricle projecting into the lateral through the foramen of Monro, with metastasis into the floor of the fourth ventricle, the aqueduct being normal. All the ventricles were dilated. Hypophysis normal. No microscopic examination of brain.
Mott, F. W., and Barrett, J. O. W. *Archives of Neurology*, 1900, vol. i, p. 417. Case 1. Man, aged 34	Headache, nausea, vomiting, dizziness, choked disc	Periodic attacks of double vision, ptosis, stupor lasting about a week, followed after some years by sluggish pupils and left ptosis	Cerebellar gait more to the left	Periodic attacks of drowsiness and stupor, tendency to somnolence, later impairment of memory, tremors in face and tongue, leading to diagnosis of paretic dementia	Weakness especially in left limbs with increased reflexes	Colloid cyst the size of a Barcelona nut situated above the optic tract, its centre corresponding to the termination of the infundibulum, attached to the choroid plexus from which it grew. Dilatation of lateral and third ventricles. Hypophysis not examined.
Case 2. Man, aged 39	Was insufficiently studied	Pupils dilated, reactions sluggish	Unsteady gait	Regarded as an epileptic and general paralytic	Epileptic attacks, increased reflexes	Myotic infection setting up new growth in body of third ventricle by irritation. Dilatation of all ventricles.
Case 3. Man, aged 28	Insufficiently studied, supposed to have had headache, nausea and vomiting	No note made	Not mentioned	Diagnosed as mania with suicidal tendencies. Was very drowsy	.. .. ..	Epidermoid cyst with numerous small cysts in third ventricle. Hypophysis not examined. Dilatation of all ventricles.
Nothnagel, H. *Wiener med. Presse*, 1889, Bd. xxx, S. 89. Boy, aged 15	Headache, nausea, vomiting, vertigo	Protrusion of both eyeballs, paralysis of associated ocular movement upward and to the left, paresis of third and sixth nerves, pupils large and reactionless	Cerebellar inco-ordination	Not mentioned ..	Not mentioned ..	Epithelial tumour growing from the choroid plexus of the third ventricle into the aqueduct of Sylvius and compressing the anterior corpora quadrigemina.

Russell. *Med. Times and Gaz.*, 1878, vol. i, p. 522. Boy, aged 15.	Not mentioned	Not mentioned	Not mentioned	Not mentioned ..	Fits and tremors	Sarcoma base of third ventricle attached to the optic commissure. Dilatation of lateral ventricle.
Sawyer. Quoted by E. Meyer, *Archiv. f. Psychiatrie u. Nervenheilkunde*, 1889, Bd xxxii. Man, aged 29	Headache, vomiting	Not mentioned	Ataxic gait..	Memory poor, speech like general paresis	.. .. ..	Echinococcus cyst in floor of third ventricle with hydrocephalus.
Saxer, F. *Zeigler's Beiträge*, 1902, Bd. xxxii, S. 338. Man, aged 46	History is very poor	.. ..	.. ..	.. .. ..	.. .. ..	Epithelial tumour growing from the epithelial lining of the infundibulum, filling up the whole ventricle. Hypophysis normal. Internal hydrocephalus.
Selke, Walter. "Inaug. Diss.," Königsburg, 1891. Woman, aged 42	Headache, nausea, vomiting, vertigo, loss of vision, choked disc	Pupils wide and reactionless, attacks of unconsciousness in which there was deviation of the eyes to the right	Uncertain gait	Attacks of unconsciousness which lasted at times eight days	Twitching in left limbs followed by left hemiplegia	Papilloma growing from the choroid plexus causing pressure on the optic chiasm. Dilatation of lateral ventricle. No microscopic examination of brain.
Scholz, Fritz. *Virchow's Archiv.*, 1906, Bd. clxxxiv, S. 255. Man, aged 30	Headache, vomiting, choked disc, blindness	Pupils equal, normal reactions	Uncertain gait	Somnolence ..	Power in left limbs diminished with diminished reflexes	Cholesteatoma of epidermoid origin, compressing surrounding structures and extending into the lateral ventricles. Dilatation of lateral ventricles. No microscopic examination.
Tannenheim, E. *Wiener klin. Wochenschr.*, 1897, S. 494. Man, aged 40	Headache, vomiting, choked disc	Not mentioned	Not mentioned	Stuporous condition	Increased reflexes	Dermoid cyst in third ventricle. Dilatation of lateral ventricles.
Wallman, Heinrich. *Virchow's Archiv.*, 1858; Bd. xiv, S. 385. Man, aged 45	Not mentioned	"Eyes weak"	Uncertain gait	Memory poor ..	Weakness in feet	Colloid cyst the size of a walnut in the third ventricle attached to posterior commissure. Also small lipoma of right lateral ventricle. Internal hydrocephalus.
Williamson, R. T. *Medical Chronicle*, 1905, p. 76. Boy, aged 12	Marked symptoms of intracranial pressure, especially headache and choked disc	Paralysis of right external and internal rectus, movement of right eyeball upwards and downwards impaired, movements of left eye impaired to the right	Tendency to fall to the right	Drowsy and comatose	Left sensory fifth involved, knee-jerks absent	Round-cell sarcoma growing from the choroid plexus of the third ventricle the size of a small hen's egg, with dilatation of the lateral ventricles. No microscopic examination of brain.

Reported by	General Symptoms	Ocular Symptoms	Inco-ordination	Mental Symptoms	Other Symptoms	Post-mortem Findings
Wilson, S. A. K. *Brain*, 1906, vol. xxix, p. 527. Case 2. Man, aged 42	Headache, vomiting, dizziness, choked disc	Left pupil larger than right, reactions slow, slight double ptosis, divergent strabismus, periodic ectopia pupillæ, later upward movements defective, on convergence only the right eye moved in, conjugate deviation to the left limited, with increased ptosis. Slight proptosis	Not mentioned	Dreamy condition	Occasional attacks of unconsciousness during which towards the last the limbs were flaccid	Colloid tumour in third ventricle attached to the ependymal wall, flattening the pons and dilating the aqueduct of Sylvius. No microscopic examination.
Woodbury, F. *Amer. Journ. Med. Sci.*, July-Oct. 1878, p. 128. Man, aged 45	Headache, vertigo, negative eye grounds	Divergent squint and diplopia	Cerebellar gait, backward staggering	Mental lethargy	Weakness in limbs, tinnitus	Gliosarcoma in third ventricle extending into and blocking up the aqueduct of Sylvius. Dilatation of lateral and fourth ventricle. Small area of softening superior surface of cerebellum.
Weisenburg, T. H. Case 1. Girl, aged 17	Headache, morning nausea and vomiting, dizziness, marked choked disc, failing vision	Weakness of both external recti, paresis of associated ocular movement and of convergence upwards and to a less extent to the left, pupils dilated and reactions slow. Slight proptosis	Cerebellar gait, inco-ordination of limbs, deviation of head to left	Memory impaired, somewhat stupid	General weakness of limbs, loss of all reflexes with retention of the plantar, weakness in lower part of left face	Large vascular-glioma growing from the ependymal walls extending into the lateral ventricle and aqueduct of Sylvius, compressing the surrounding structures. Continuous with optic thalamus. Growth bisected almost completely the cerebral peduncle anterior to the aqueduct, destroying almost wholly the third nuclei, and compressing the red nuclei, and destroying the commissural fibres. Dilatation of lateral ventricles.

Case 2. Girl, aged 20	Failing vision, headache, nausea, vomiting, dizziness, choked disc	Great protrusion on both eyeballs with downward deviation, ptosis of both upper lids with dilatation of veins, paralysis of associated ocular movement and of convergence upward, less to the right and left and only a little downwards. Pupils large and reactionless	Early cerebellar gait. Questionable ataxia of limbs	Stupid apathetic condition	Because of involvement of the thalamus had central pains and vasomotor and trophic phenomena, involuntary yelling and deviation of the body to the opposite side. Besides, had weakness in right motor fifth, lower seventh and tongue, due to involvement of knee of internal capsule. Loss of reflexes with the exception of the plantar	Glioma growing from the ependymal walls of the left lateral ventricle, extending into the third through the foramen of Monro and occupying the anterior portion of the third ventricle. The tumour extended into the left thalamus, destroying most of the anterior nuclei. Dilatation of lateral ventricles.
Case 3. Man, aged 27	Headache, nausea, vomiting, dizziness, choked disc	Loss of vision was first noticed when head was inclined to one side. When body was held rigid with head tilted back vision was best. When head was tilted forward vision would gradually fade and would return on resuming an erect posture. Failing vision was accompanied by marked headache and dizziness	None ..	None	None	Colloid cyst the size of a small marble attached to the choroid plexus in the upper anterior portion of the third ventricle posterior to the middle commissure, so situated that it could close the foramen of Monro. Marked dilatation of lateral ventricles with little of third.

Dr. Arthur Hall, of London, reported two cases of tumour of the third ventricle before the Pathological Society, but I have been unable to obtain a report of them.

would cause little pressure upon the surrounding structures, whereas a similar growth near the Sylvian aqueduct or the foramina of Monro might cause in the former the symptoms of pressure upon the oculomotor nucleus and superior cerebellar peduncle, and in the latter, besides dilatation of the ventricles, there may be no other symptoms, with the exception that if the tumour is small and movable, such as Case 3 (Weisenburg), there would be a closure or opening of the communications between the lateral and third ventricles by alterations in the position of the head; but this, of course, is exceptional.

The larger growths may be limited to the ventricle, or may grow by extension into the surrounding cavities. The tendency is nearly always to grow from the third to the fourth ventricle, through the aqueduct of Sylvius, in the direction of the flow of the fluid, rather than into the lateral ventricle. Of the collected cases, three only extended into the lateral ventricles. Here the tumour did not actually enter the ventricles, but only projected through the foramina, owing principally to its situation in the anterior portion of the cavity. But in seven cases there was extension into the aqueduct of Sylvius. It is interesting to observe that in three of these (Weisenburg, Case 1, Bielchowsky, and Henneberg) the tumour grew ventrally from the aqueduct into the cerebral peduncle, almost bisecting it destroying the oculomotor nuclei, compressing and separating the red nuclei; while in three other cases (Calonzi, Nothnagel, and Woodbury) the posterior part of the cerebral peduncle and pons was much compressed, with no forward extension. In Finkelnburg's case the growth affected the posterior part of the peduncle and pons, especially the right, and compressed the anterior corpora quadrigemina. In this connexion Meyer's case is interesting because there was metastasis to the fourth ventricle, the aqueduct escaping. In another case reported by Finkelnburg (Case 8) a sarcoma grew in the third ventricle, and extended into the lateral ventricles and aqueduct of Sylvius as well as the surrounding structures. The hypophysis was affected.

It can be seen, then, that, so far as the symptomatology is concerned, it is necessary to make three distinct classifications—(1) those cases in which a tumour of moderate size is situated in the floor of the third ventricle, and in which there is no extension into the foramina of Monro or aqueduct of Sylvius; (2) small tumours so situated as to obstruct the foramina of Monro, and whose position can be changed by deviation of the head; and, lastly, (3) tumours, whether large or small, which either extend into the aqueduct of Sylvius, affecting the surrounding structures by direct extension or pressure, or those in which the posterior portions of the cerebral peduncle and pons are compressed either by direct pressure or dilatation of the aqueduct of Sylvius. These will be discussed in order.

FIRST CLASS.

Those tumours which enter into this classification do not offer specific symptoms, but depend upon those of pressure on the surrounding structures. As has already been mentioned, all growths of the third ventricle cause internal hydrocephalus, and therefore its symptoms of this condition will be discussed first, as they apply to all the classifications.

In the collected cases they consisted principally of headache and choked disc, and to a less degree of nausea and vomiting and of dizziness. In nearly all there was also cerebellar inco-ordination. As can be seen, the general symptoms of increased intracranial pressure were present which are produced either by tumours of the posterior cranial fossa or by internal hydrocephalus, the differential diagnosis between them, as is well known, being sometimes impossible.

It might be expected that large tumours in this area would cause thalamic symptoms, but, as has already been mentioned, this does not often occur, and even if there is general pressure on the thalamus no specific symptoms would be manifested excepting in those cases in which there is direct destruction, as in Case 2 (Weisenburg), in which there were central pains, vasomotor and trophic disturbances, principally on the side opposite the lesion, involuntary howling and deviation of the body to the opposite side, this being the beginning of a progression movement. In only three other cases of the thirty was the thalamus affected, but there were no symptoms mentioned referable to it.

In tumours of large size some indirect pressure is nearly always exerted on the internal capsule of one or both sides, and there should be present corresponding paresis of the limbs; but, as is well known, this sometimes also occurs in internal hydrocephalus, and yet it should be more common in large tumours of the third ventricle, because there is more likely to be also pressure on the internal capsule. It should be remembered that in internal hydrocephalus the paresis may result from cortical pressure. It can be seen, then, that the combination of these conditions should more readily produce paresis of the limbs. Of the collected cases, in seven there was paresis of one side and in five of both, and, while this occurred in twelve only of the thirty cases, in those in which it was absent the tumours were so small that no pressure was exerted upon the surrounding structures.

The character of the paresis is that seen in internal hydrocephalus—that is, a paresis without a well-defined paralysis, there being nearly always spasticity of the limbs, although they may be flaccid. The reflexes nearly always are increased, but sometimes may be normal or diminished.

Somehow the impression has gained ground that lesions of the third ventricle may cause mental symptoms, such as a drowsy, apathetic dull mentality, and often greater impairment. In a number of the collected cases the mental condition was that of general paresis (Henneberg and Mott and Barratt, Cases 1 and 2), while Meyer's case presented the symptoms of Korsakoff's psychosis. In sixteen there was present either a dull, stupid mentality or a decided tendency to somnolence or drowsiness; while in Case 1, Mott and Barratt, there were "recurrent attacks of drowsy stupor, dementia and slowness of thought, speech and movement, and tremor of the tongue and face, so that at one time the patient simulated an epileptic, at another a general paralytic, and then again became almost sane." Mott thought that the mental symptoms were the result of compression of the cortex by the internal hydrocephalus, and explained the recurrences by the escape of fluid from the lateral ventricles, thereby relieving the cerebral compression and removing the cortical anæmia.

Purves Stewart [3], in discussing the causes of drowsiness, believes that it might result from "upward pressure on the floor of the third ventricle whether this be by direct pressure on the ventricle and Sylvian aqueduct, or whether, as Franceschi suggests, it be the result of cerebral anæmia from compression of the arteries of the circle of Willis between the upper surface of the growth and the under surface of the brain. The curious intermissions in the drowsiness might be explained on either hypothesis, either by variations in the tension of a cystic tumour or by alterations in the direction of the growth with relation to the superjacent vessels."

John Turner [4] disagrees with Stewart's conclusions, and believes that the drowsiness is due to a cerebral œdema. It has been claimed by some that coma may be produced by a deprivation of the secretion of the hypophysis. This does not enter into the discussion of tumours within the third ventricle, because all those in which the hypophysis was involved were rejected. Again, in one of Stewart's cases in which the hypophysis was entirely destroyed there was no stupor.

It is possible that the drowsy, somnolent condition which is so frequent an accompaniment of tumours in the third ventricle is brought about by impairment of the normal function of the cortex, the result of pressure against the skull through dilatation of the lateral ventricles, and is not a specific symptom resulting from lesions of the third ventricle.

SECOND CLASS.

It would seem hardly necessary to make this classification, inasmuch as there is only one tumour (Case 3, Weisenburg) which enters into it. The patient, a man, first noticed failure of vision on bending his head to one side, and, with the accompanying symptoms of intracranial pressure, had most vision and less general discomfort when his body was erect, with the head tilted backward, while any deviation from this posture caused increase in his headache and nausea, with total loss of vision, which would return on resuming the primary position. At necropsy a tumour was found attached to the choroid plexus, the size of a small marble, situated in the upper anterior portion of the third ventricle, in front of the middle commissure closing the foramina of Monro. It was so loosely attached that undoubtedly deviation of the head might have caused the growth to be moved from its position.

It is rather difficult to explain what occurred in this case. It is apparent from its situation that there was a gradual closure of the foramina of Monro, which produced a dilatation of the lateral ventricles, the third being only slightly dilated. The patient felt most comfortable and had most sight with his head tilted backward, probably because in this position there was established free communication between the lateral and third ventricles. While it is explicable that the headache and nausea were increased by the closure of the foramina of Monro, which occurred when the head was tilted forward, inasmuch as in this position the tumour effectually closed up the foramina of Monro and increased the pressure in the lateral ventricles, it is rather difficult to understand how this would cause total loss of vision, and yet this is the only explanation possible, inasmuch as tilting the head backward caused return of sight.

If, then, an increase in the intracranial pressure in the lateral ventricles can cause headache and nausea evidently through pressure on the cortex, just so there might have been produced by pressure on the occipital cortex failure of vision. It must be remembered that the patient had choked disc and only one eye, the other having been removed because of an injury, and that sight at best was impaired.

Alterations in the general symptoms of tumour, particularly vomiting and dizziness, have been observed, especially in cerebellar tumours, and less so in tumours of other areas. The usual explanation given is that in certain positions of the head there is interference or closure of the communication between the ventricles, especially in the aqueduct, this causing increase in intracranial pressure; but I have been unable to find an instance in which vision was similarly affected as in the case above mentioned.

THIRD CLASS.

It is upon the cases which come into this classification that a definite diagnosis can be made, and in which it is possible to establish a fairly well recognizable symptom-complex. The diagnosis is dependent entirely upon the fact that there is involvement either directly or by pressure of the oculomotor nuclei, the red nuclei or the superior cerebellar peduncles, and pressure or destruction of the posterior longitudinal bundle, or the intercommunicating fibres between the third nuclei. In some of the cases which come under this classification the anterior corpora quadrigemina were also pressed upon.

In the *résumé* of the reported cases it will be seen that most of the observations were very poor, and that in many of the cases in which the oculomotor nuclei were directly affected no mention whatever is made of ocular symptoms. So far as paralysis of associated ocular movement is concerned, there are very few observations indeed, especially in the older reported cases when the causes of "Blicklähmung" were not well recognized.

Within a few years it has been definitely established that lesions near the aqueduct of Sylvius cause paralysis of associated ocular movement upward and more rarely downward, and that impairment of lateral deviation is caused by affection of the posterior longitudinal bundles.

Of the instances of third ventricle tumours in which there occurred "Blicklähmung" four types of lesions can be differentiated:—

(1) Those in which the lesion was above the aqueduct of Sylvius, such as Case 2 (Weisenburg), in which the tumour was in the upper anterior portion of the third ventricle, and in which there was no direct involvement of the oculomotor nuclei. Microscopically, however, the cells were distinctly diseased, and there was besides a definite internal hydrocephalus with dilatation of the aqueduct. It is probable that the paralyses of associated ocular movement in this case were the result of disease of the third nuclei from pressure. In this case, besides para-

lysis of upward movement, there was impairment to the right and left and slightly downwards.

(2) In the second type the pressure is more direct, such as in Wilson's case, in which the tumour did not extend into the aqueduct, but compressed directly the upper part of the peduncle and pons. In this case there was weakness of upward associated ocular movement and of conjugate deviation to the left.

(3) In the third type are those cases in which, while the tumour extended into the aqueduct, the surrounding structures were involved by pressure, there being no extension. Such were the cases of Nothnagel and Calonzi. In the former there was associated weakness upward and to the left, and in the latter weakness only in an upward direction. In Woodbury's case the tumour extended into the aqueduct, but the only note made is that there was divergent squint and diplopia. Considering, however, the early report of the case (1878) "Blicklähmung" might have been overlooked.

(4) In the fourth type are those cases in which the growth extended into the aqueduct of Sylvius and from it ventrally, bisecting the peduncle and causing almost complete destruction of the oculomotor nuclei. This was true in the cases of Bielchowsky, Weisenburg (Case 1), Henneberg, and Finkelnburg. In the first there was paralysis of associated ocular movement upwards and downwards, lateral movements being also impaired. In my case there was paralysis of associated ocular movement and of convergence upwards and less to the left, while in Henneberg's case there is no mention of this symptom, although the nuclei were distinctly diseased, as were also the red nuclei, no mention being made also of inco-ordination. In Finkelnburg's case the statement is made that all the muscles of both oculomotor nuclei were affected, but that, on account of the mental condition, closer observation was impossible.

It is evident, then, that in lesions of the third ventricle, whether because of direct or indirect pressure from above or by direct affection of the oculomotor area, there occurs paralysis of associated ocular movement, predominantly in an upward direction and more rarely downward and to either side. With the exception of Bielchowsky's case and Weisenburg's Case 2 there was no mention of paresis of downward associated ocular movement. In all the other cases, in association with paralysis of upward movement, there was impairment of associated ocular movement either to one side or both sides.

With "Blicklähmung" there should be paralysis of convergence in the same directions. With the exception of my own cases, however, this was mentioned only by Bielchowsky. The question of convergence, while apparently simple, has by no means been threshed out. By most text-books and writers on this subject one is left under the impression that convergence is possible only in a median direction, and the statement is constantly made that there is paralysis of associated ocular movement, but that convergence in the same direction is possible, which is manifestly contradictory, for converging movements are in their very essence associated. The truth of the matter is that convergence is normally possible in all directions, and the writer is of the opinion that all ocular movements are in convergence.

Of the other ocular symptoms which occur in such lesions the condition of the sight and pupils can be dismissed, for the former is nearly always impaired because of the choked disc, the condition of the pupils being dependent upon the same condition as affection of the third nerve nuclei.

In those cases in which there is direct affection of the oculomotor nucleus there are, of course, oculomotor palsies. This was true in the case of Nothnagel, Finkelnburg, Wilson, Bielchowsky, and Weisenburg (Case 2), in which were present ptosis and pupillary irregularities only.

Protrusion of the eyeballs was present in four cases (Nothnagel, Wilson, and Weisenburg, Cases 1 and 2). In another communication I have discussed the occurrence of exophthalmos in brain tumour, and have come to the conclusion that it occurs only in those cases in which there is either direct pressure on the cavernous sinus or the veins of Galen, this leading either to stasis of the vessels of the orbits or thrombosis of the cavernous sinus. It should be expected then that large tumours of the third ventricle should occasionally cause protrusion of the eyeballs because pressure may be exerted upon both structures.

In a number of cases there was present paralysis of the sixth nerve either on one or both sides, this being presumably due to pressure.

A most constant symptom, and one which was present in fifteen of the cases, was ataxia, which was always of the cerebellar type, the description of the gait being drunken or ataxic, there being staggering to either side and sometimes forward and backward. Besides there was mentioned in the majority of cases ataxia of the limbs. These can be undoubtedly accounted for either by a direct involvement of the red nuclei or the superior cerebellar peduncles, or by pressure upon the same structures due to dilatation of the third ventricle, or of the aqueduct of Sylvius.

The occurrence of cerebellar ataxia in internal hydrocephalus is well known, and the literature is replete with cases in which clinically the diagnosis was made of cerebellar tumour, but which pathologically demonstrated dilatation of the ventricles. The ataxia in these cases may be due to pressure on the cerebellum brought about by direct dilatation of the fourth ventricle or of the posterior horns of the lateral ventricles, but most commonly is caused by pressure upon the red nuclei or superior cerebellar peduncles. This no doubt accounts for the frequent presence of this symptom, for internal hydrocephalus was present in all but three cases in which accurate observations were not made. The conclusion, then, can be drawn that ataxia of the cerebellar type should be present in tumours of the third ventricle.

Besides the more specific localizing symptoms of "Blicklähmung" and ataxia, there were present in the cases which enter into this classification the general symptoms which have already been enumerated under the first class—that is, of increased intracranial pressure and of pressure upon the surrounding structures, for most of these tumours were of considerable size.

The symptom-complex which has been enumerated as resulting from lesions of the third ventricle which encroach upon the structures surrounding the aqueduct of Sylvius may sometimes result from lesions of this part or of the pineal gland, and yet it is possible to make a differential diagnosis.

In lesions of the pineal gland, as mentioned by Frankl-Hochwart [1] and Howell [2], there may be besides the general symptoms of tumour, "Blicklähmung," pupillary disturbances and ataxia, abnormal growth in length, unusual increase of hair, adiposity, premature sexual development, and mental precosity, none of which occur in lesions of the third ventricle. Again, as emphasized by Howell, paresis of the limbs is uncommon in tumours of the pineal gland, although internal hydrocephalus is not infrequent.

The differentiation from tumours of the anterior corpora quadrigemina is more difficult, because its symptoms are dependent upon pressure on the oculomotor nuclei, and less so on the red nuclei or superior cerebellar peduncles. The diagnosis would largely depend upon the fact that third ventricular tumours cause more symptoms because of their tendency to affect a larger number of structures; there is nearly always paresis of the limbs on one or both sides, and ataxia, the former being uncommon in tumours of the anterior corpora quadrigemina. Again, in disease of the anterior corpora quadrigemina there would be a greater tendency to disturbance in hearing, because of affection of the posterior corpora quadrigemina.

The conclusions drawn from the study of the cases of third ventricular tumours are:—

(1) Tumours within the third ventricle growing either from the ependymal walls or the choroid plexus are uncommon; thirty cases with necropsy have been reported altogether.

(2) Their nature varies, and has no direct bearing on the symptoms.

(3) Tumours within the third ventricle have a tendency to grow in the direction of the flow of the cerebrospinal fluid—that is, towards the fourth ventricle through the aqueduct of Sylvius.

(4) Internal hydrocephalus nearly always occurs, either because of interference with the flow of the fluid or the function of the choroid plexus.

(5) Growths within the third ventricle do not cause specific symptoms, and their recognition depends entirely upon the symptoms of pressure on the surrounding structures. Three divisions can be made:—

(*a*) Tumours of moderate size limited to the third ventricle, presenting the symptoms of internal hydrocephalus, with the addition that there is nearly always paresis of the limbs of one or both sides, and possibly affection of the thalamus.

(*b*) Tumours so situated as to obstruct the foramina of Monro, cause dilatation of the lateral ventricles, and their position can be changed by deviation of the head, producing variation in the symptoms.

(*c*) Tumours which attack the parts surrounding the aqueduct of Sylvius either by direct pressure or after extension into the aqueduct by growth of the tumour ventrally, cause the following symptoms: Paralysis of associated ocular movement and of convergence upwards and, less commonly, to either side and downwards, ataxia of the cerebellar type, as shown in the gait, station or voluntary movements of the limbs, at times ptosis of the upper lids and protrusion of either one or both eyeballs, generally large pupils with impaired reactions, paresis of the limbs of one or both sides, either with increased, normal, or diminished reflexes, and the general symptoms of tumour, as headache, choked disc, nausea, vomiting, and vertigo.

(6) Lesions of the third ventricle do not cause specific mental symptoms; the occurrence of mental symptoms is dependent upon the compression of the cortex against the skull, resulting from internal hydrocephalus.

The histories of the cases are as follows:

CASE 1.—Mary C., 17 years old. Admitted to the Medico-Chirurgical Hospital, June 29, 1908. Her family and previous history were unimportant. Six months before she came under observation her menses ceased, but returned again about three months afterwards, when she first began to complain of weekly headaches, frontal in character. Six weeks later, or about two months before she was examined, the headache became constant, appearing in the morning and lasting all day. During her whole history this pain was of the same intensity, the patient describing it as a sharp and then again as a dull pain over the right side of the head and neck, right eye, and sometimes over the left. Coincident with the headache she felt sick, this appearing early in the morning and lasting until about noon. There was at the same time a tendency to vomit, but with two exceptions she never vomited.

Dizziness did not become apparent until three weeks before she came under observation, or about two months after the onset of the headache and nausea. She could not describe it any more than when she got up in the morning her head felt light and dizzy, but there was no distinct history of swaying, either of self or of objects. She was able to walk up to this time, and then noticed on arising that she would stagger as if drunk. She thought that at the same time her limbs became weak, but she meant by this that she would stagger and fall because of the ataxia rather than the result of any weakness in her limbs.

Her sight became poor, but the time of its onset could not be recalled. She thought it might have been six weeks before she came under observation. Coincidentally with the staggering she began to see double, objects appearing side by side, but not persistently. She never fainted or suffered from roaring in her ears, and hearing was good. There had never been disturbance of bladder and rectal functions. Her mentality was impaired, for it was only after repeated questioning that the history was obtained. From the very onset of the headache the patient inclined her head to the left, sometimes the ear almost approximating the left shoulder. This she did because, in this position, the intensity of the pain was diminished.

When admitted to the hospital, examination demonstrated a girl who, when lying in bed, had a tendency to incline her head to the left, this becoming much more apparent when she got up and attempted to walk. Her gait was distinctly cerebellar, walking with her feet wide apart with a tendency to stagger, especially to the left. Closing the eyes had no influence upon the ataxia. There was no tenderness to pressure anywhere over the head, but she seemed to wince a little when pressure was applied over the right cerebellar area.

Ophthalmoscopic examination by Dr. L. Webster Fox demonstrated a choked disc on both sides of about six dioptres. The pupils were dilated, and their reactions both to light and movement impaired. Vision was greatly diminished. There was a little bulging of the eyeballs. Ocular movements showed a weakness of both external recti, especially to the left. When asked to look upward there was a decided hesitancy in the beginning of the movement and the range was impaired, especially of the left eye, in which there was present an irregular rotatory jerking. The paresis of associated ocular movement upward, however, was not complete. There was no hesitancy or jerking of the eyeballs when looking to the right, but when attempting to look to the left a rotatory movement of the left eye occurred and there seemed to be lagging of the left eyeball. Downward movement was well performed. When following a finger the same hesitancy and paresis in upward associated movement was noticed, as well as to the left. She could converge well downwards and in the median line, but when following a finger in the median line in an upward direction there was present a corkscrew-like movement of the eyeballs, the range becoming wider as the upper plane was reached, the left eye taking greater part in the movement. The same corkscrew-like movement was present when convergence was attempted from above downward, the range of the movement becoming less. Upward convergence could not be accomplished. With one eye closed both the voluntary and involuntary movements of the other eyeball seemed similar to when both eyes were exposed.

The brow could be wrinkled normally on both sides, but when the mouth was opened there was a distinct drooping on the left side. The patient could, however, wink the eye and show her teeth almost equally well on both sides. The masseters contracted well on either side, and the jaw opened in the median line. The tongue was protruded straight, there being no tremor or atrophy.

The upper limbs were well formed, there being no atrophy anywhere. Their tonicity was about normal. The grip in both hands was good, it being perhaps better on the right, the patient being right-handed. The resistance to passive movement of the upper limbs was good and about equal on both sides. The biceps and triceps reflexes were absent. Finger-to-nose test demonstrated ataxia, a little more on the left. Supination and pronation of the forearms soon showed a lagging of movement, the left arm becoming inco-ordinate first.

The lower limbs were well formed, there being no atrophy anywhere. Their tonicity was normal, and power was not at all diminished. The patellar and Achillis jerks on both sides were absent, even on reinforcement. Plantar irritation caused flexion of the toes on both sides. There was no disturbance of the sense of position or of movement, but the heel-to-knee test demonstrated ataxia of both lower limbs, distinctly more so of the left. Closure of the eyes did not increase the ataxia. Sensation for touch and pain was everywhere normal.

An exploratory operation was performed by Dr. Stillwell Burns several days after she came under observation. The left cerebellar area was exposed, but nothing was found. The patient did not do well under anæsthesia, and never regained consciousness, dying several hours after removal from the operating table. The autopsy was performed the following day, and the brain only removed.

Macroscopic Examination.

The tumour is entirely in the third ventricle and is in the shape of a lobulated egg, its anterior part projecting into the lateral ventricles through

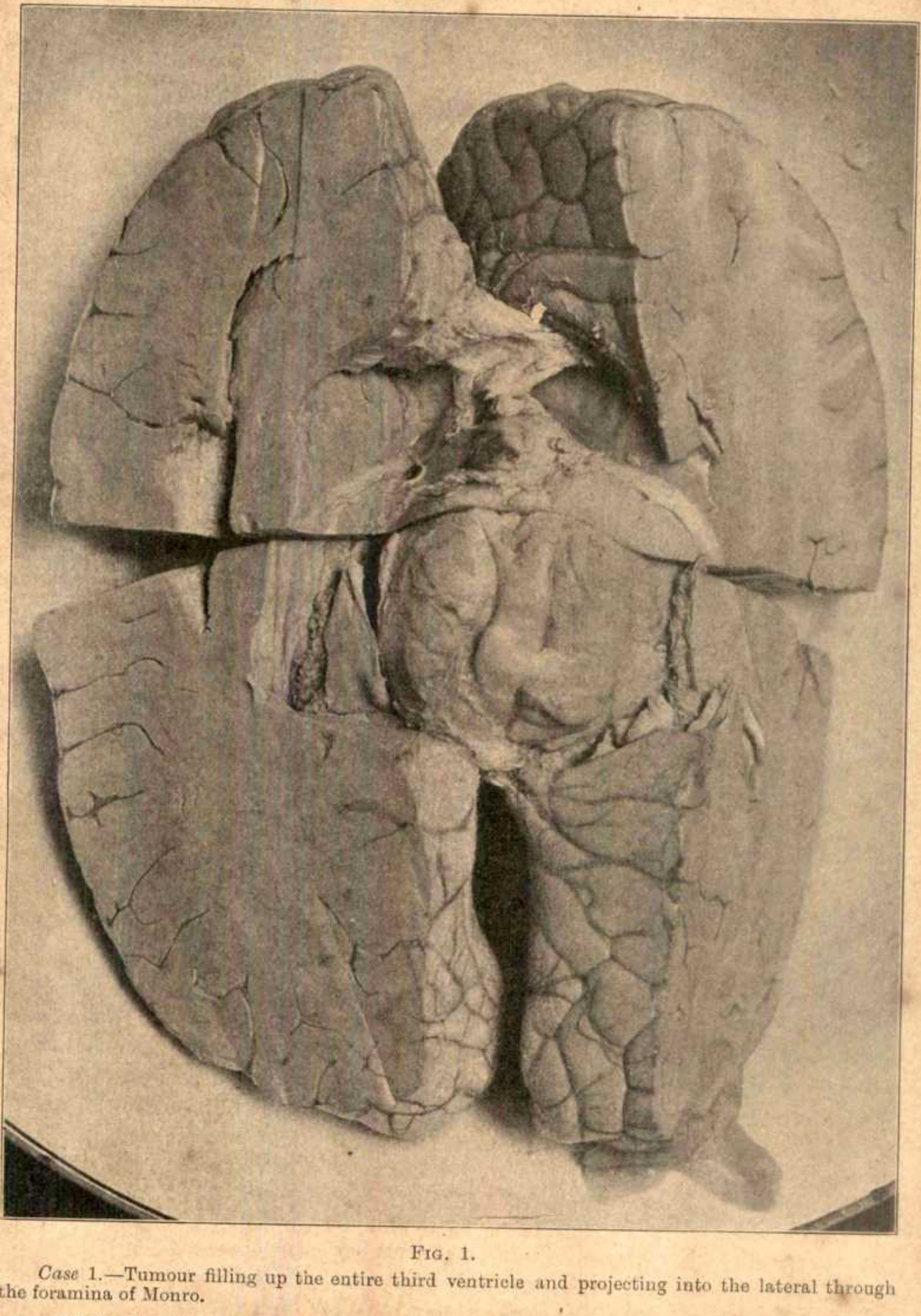

FIG. 1.

Case 1.—Tumour filling up the entire third ventricle and projecting into the lateral through the foramina of Monro.

the interventricular foramina, pushing the fornix and the lamina lucidum forward and more to the right, separating widely the caudate nuclei.

Posteriorly the tumour is round and extends by means of the aqueduct of Sylvius into the anterior part of the cerebral peduncle and the uppermost portion of the pons. The lateral ventricles are much dilated.

Inferiorly it extends to the base, dilating the infundibulum. The optic chiasma is considerably compressed. The mass of the growth leans more over to the right, compressing on either side the optic thalamus, and is continuous in part with the right. In the upper level the tumour is attached to the ventricular walls on either side, but is free below. Laterally the growth compresses, besides the thalami, the lenticular nuclei more on the right, and to some extent also the fibres of the right internal capsule. It measures 2¼ in. in length, 1¼ in. in depth and 1½ in. from side to side. The hypophysis is normal.

Microscopic Examination.

The *tumour* is uniform in its growth and is rich in cells which are tightly packed together, especially in its border. They are round, oval, or spindle shaped, and by the hematoxylin-eosin stain are granular in appearance. The nuclei are large, and in relation to the cell are surrounded by little protoplasm. There is very little intracellular substance, which by the neuroglia stain shows no fibres. The growth is very vascular, especially in its centre, and numerous widely dilated capillaries full of red cells and pigment are present. Occasionally the walls of these capillaries are ruptured, causing an exudation of blood-cells into the surrounding tumour tissue. In the inferior portion the outline of the growth is definite and the ependymal cells of the walls of the third ventricle can be traced both inferiorly and laterally. In its upper level the growth is continuous on each side with the ependymal walls and on the right with the thalamus. The nerve cells in both thalami are slightly degenerated and the internal capsule on the right side is slightly displaced, although no degeneration is found.

Cerebral peduncle and pons.—Cross-sections show that the tumour has extended into and obliterated the aqueduct of Sylvius, completely filling it up, extending in a wedge-shaped manner downward, bisecting the peduncle from above downward—that is, from the part where the aqueduct should be to the interpeduncular space, there remained only enough tissue in the anterior part to connect the two peduncles. The red nuclei on either side are deviated laterally, and the cells of both third nuclei in anteriorly are almost completely obliterated; only a few remain, which are diseased, while in its posterior portion, though fewer cells are destroyed, no normal cells can be found. The fibres of the posterior longitudinal bundle are replaced either by the tumour growth or deviated to one side. Some of the intra-medullary third nerve fibres are partially degenerated on either side, and there is complete destruction of all the fibres in the median raphe. The central grey matter surrounding the aqueduct is replaced by tumour cells, and there is also some degeneration of the fibres of the fourth nerve. The tumour in its anterior median part is free, growing into a cavity

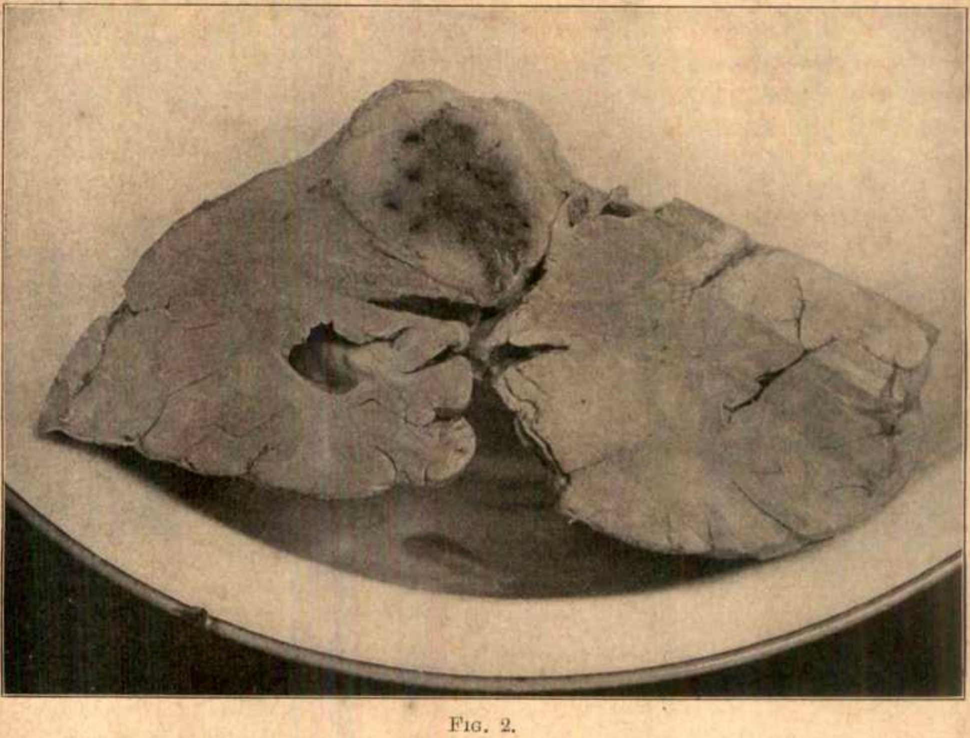

FIG. 2.

Case 1.—Vertical section showing outline of tumour, which is continuous with the right thalamus.

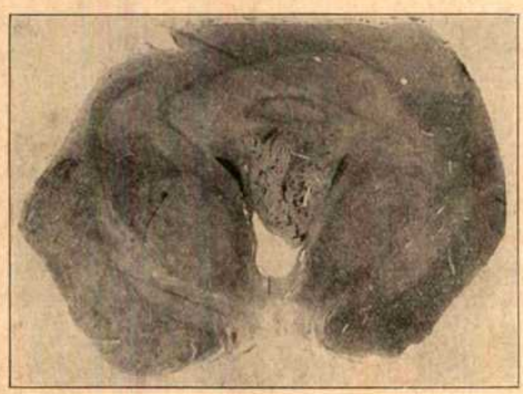

FIG. 3.

Case 1.—Photograph of cerebral peduncle, showing extension of tumour into the aqueduct of Sylvius; it grew ventrally, destroying the oculomotor nuclei and the commissural fibres, separating widely the red nuclei.

which has evidently been caused by it, but laterally there is an imperceptible merging, and tumour cells can be found in every part of the section. The foot of the cerebral peduncle, the lateral fillet, and the corpora quadrigemina are normal, although tumour cells can be found within these structures.

Sections made lower down in the cerebral peduncle and upper part of the pons show that the tumour has attacked the grey matter surrounding the aqueduct of Sylvius, irregularly infiltrating the surrounding structures, in the entire extent of the cerebral peduncle and the uppermost portion of the pons; the aqueduct with its ependymal cells is first seen flattened out with approximating walls at the region of the fourth nuclei. The cells of the fourth nuclei are few only in number, are much diseased, and are infiltrated and surrounded by tumour cells. Sections made at the level of the fifth nucleus show no trace of the tumour. No degeneration is found in the posterior longitudinal bundles, the lateral or median fillet, or in the motor nucleus. The medulla and cerebellum are normal.

The *cranial nerves*, with the exception of the second, third, and fourth, are normal. In the third nerves some of the axis cylinders are swollen, while in other areas they have disappeared. In places the myelin sheaths are greatly enlarged. The degeneration in the second nerve is not as great as that in the third.

CASE 2.—Reported in full, with Dr. W. F. Guilfoyle, in the *Review of Neurology and Psychiatry*, June, 1910. A girl of 20, with a history of rheumatism, began gradually to lose vision. This was accompanied by flashes of light and double vision. Very soon afterwards she complained of headache, which was frontal and occipital, nausea, vomiting, and dizziness. She had several convulsions, which affected the left limbs, especially the arm, and during which time the eyes and head were deviated to the right. Soon afterwards she began to complain of pain all over her body, and especially of flashes of heat and prickly sensations in the legs, shoulders, and back, and, later, in the left arm. Vision became completely lost, choked disc developed on both sides, and was later followed by optic atrophy. Mercurial inunctions were of no value. About two months after the beginning of her symptoms she developed a slight ptosis of both eyeballs, more of the right, with unequal pupils, the reactions to light and movement being lost. There was marked exophthalmos of both eyeballs, more on the right, their axis being directed downward at an angle of 45 degrees. There was complete paralysis of associated ocular movement upwards, less to the right, still less to the left, and less so downwards. Convergence was lost in all directions, excepting in a downward median direction, and in this only an attempt was noticeable. The right motor fifth and tongue were paretic throughout. The lower portion of the right seventh nerve was weak. Hearing tests were unsatisfactory. The upper and lower limbs were weak and somewhat ataxic, although this was never satisfactorily demonstrated. All the reflexes were lost with the exception of the plantar. Sensation at no time was disturbed anywhere over the body. Incontinence of urine and fæces developed. The mentality of the patient gradually became worse. The pains and flashes of heat were constantly complained of, and erythematous and acneiform eruptions, which were not persistent, appeared. Hallucinations of sight and hearing developed, and the ocular symptoms persisted to the end. There was no difficulty at any time in talking and swallowing, but she would at times yell without provocation. The patient had a constant tendency to roll the body and head to the right.

At the necropsy a vascular glioma was found in the left lateral ventricle extending into the third by means of the foramen of Monro. In its growth it pushed the structures before it, compressing the choroid plexus, the veins of Galen, the velum interpositum, and affected in part the left thalamus. In the third ventricle it occupied the upper anterior portion. The right thalamus was not at all affected, but the walls of the third ventricle were infiltrated with tumour tissue throughout. The cells of the third nuclei were distinctly diseased, but the posterior longitudinal bundles were not degenerated. All the ventricles were much dilated, as well as the aqueduct of Sylvius. There was degeneration of the posterior roots of the spinal cord.

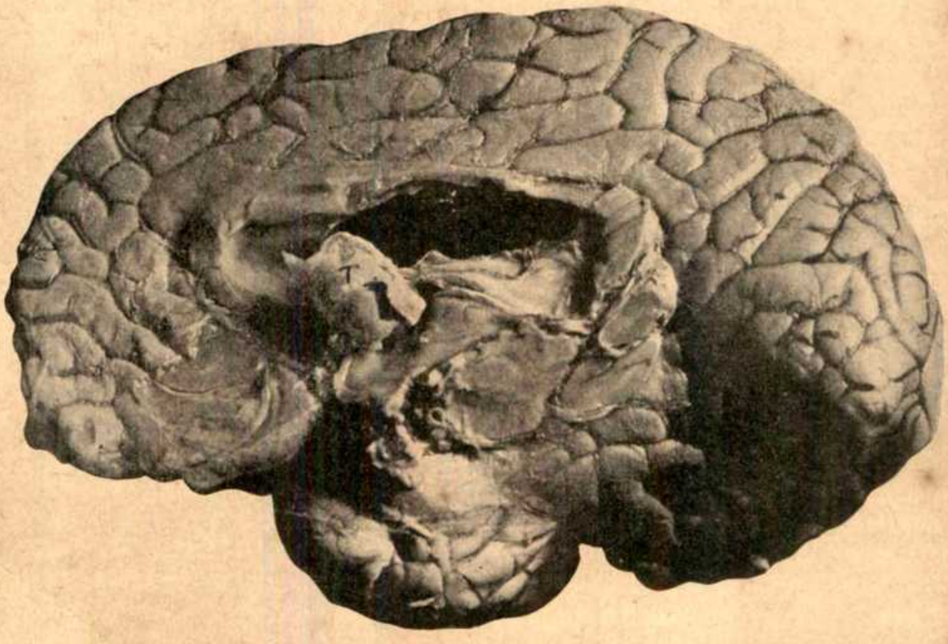

FIG. 4.

Case 3.—Colloid tumour (T), in the upper anterior portion of third ventricle compressing the foramina of Monro. Lateral ventricle much dilated. Third ventricle almost normal.

CASE 3.—The history and material of this case were kindly furnished me by Dr. L. Webster Fox, the patient not having been seen by me during life.

E. P., at the time of death 27 years of age. The history was that in 1903 the left eye was injured, necessitating its removal. The patient was well after this for about three years, when he noticed that on bending either to the right or left he could not see well. At the same time he developed severe frontal headaches, nausea, and vomiting, which came on without apparent cause. With this he noticed that vision even in an erect posture in his remaining or right eye was not as good as it should be, and for this he consulted Dr. Fox. When examined he had a well-marked choked disc. From this time on the general symptoms of headache, nausea, and vomiting increased and vision became gradually poorer. The patient noticed, however, that if he held his body erect with his head tilted backward, vision was best, and that bending the head forward or to one side caused complete disappearance of sight, which would return on resuming an erect posture. The patient, in describing the return of vision, said " that he would first see a light-bluish point, then vision would gradually enlarge like an iris diaphragm until the whole field would come in."

Headache and nausea were less when his body was erect with head tilted back, and would also increase when bending forward or to one side. These were the only symptoms presented. Death occurred suddenly.

At necropsy a tumour about the size of a marble was found in the upper anterior portion of the third ventricle, it making a slight but equal groove for itself in both optic thalami. As is shown in Fig. 4, the growth was just anterior to the middle commissure, which was not distorted or pressed upon, and the foramina of Monro, which were dilated, were evidently closed up by the growth. The lateral ventricles were much dilated, the third ventricle being enlarged only a little. The aqueduct of Sylvius was normal. The tumour was almost round, whitish in appearance, and was easily displaced from its groove. It was loosely attached to the choroid plexus and in such position that it could very easily close up both foramina of Monro. It would also have been possible for it to be displaced from its groove by deviation of the head. Microscopic examination demonstrated a colloid cyst.

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CENTRAL NERVOUS RESPONSE TO PERIPHERAL NERVOUS DISTORTION.

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PART I.

IN 1900 Kennedy published the results of his experiments on cortical stimulation after nerve crossing [1]. Briefly stated, his experiments consisted in crossing the flexor and extensor nerves of the fore-paw of a dog, and then, after a suitable time-interval for regeneration, in stimulating the flexor centre in the cortex of the opposite side. Such stimulation produced extension, and not flexion, of the limb in question. Stimulation of the corresponding region in the opposite hemisphere produced normal flexion in the contralateral and normal fore-paw. These experiments of Kennedy have a direct bearing upon some work on the central nervous system upon which we have for some time been engaged. From many points of view it is a matter of considerable importance whether they are quite beyond the reach of critical attack. The only objection that could, we think, be urged against Kennedy's conclusions is that, as these flexion and extension centres in the dog are not widely separated from each other, and as the cortical configuration is very variable, a legitimate doubt may arise as to his having stimulated a flexion centre only and not included a portion of the extension centre through spread of the exciting current. It appeared to us, therefore, desirable to perform some experiments with the same end in view as Kennedy's, but with the operative interference such that a limb received its innervation, in whole or in part, from contralateral spinal roots. If, then, this limb showed movement on stimulation of the ipsilateral motor cortex, Kennedy's conclusions would be confirmed and no question could be raised as to the accidental stimulation of the contralateral cortex. The fore-limb of the dog was chosen, and the operation carried out on the brachial plexus. It was early discovered that to interchange the opposite cords of the plexus, or even to cross mutually one of the main cords, was surgically impossible. We contented ourselves, therefore, with suturing the proximal end of one (the left) middle cord, cut as distal as possible, to the distal end of an opposite cord cut as proximal as possible.

As in Kennedy's experiments the time-intervals that elapsed between peripheral nerve regeneration and cortical stimulation were on the short side, we determined to allow a somewhat longer period for any educative process to be established in the central nervous system.

Methods.

The primary operation in each case was carried out under full anæsthesia produced by morphine injection, followed by chloroform-ether mixture. Ordinary aseptic and antiseptic precautions were taken, and the wound in each case healed by first intention. The nerves were sutured with chromicized gut, and irregular unions prevented by enclosing the unsutured proximal stump in rubber tubing. The dog was carefully tended in a special kennel. When regeneration was established, the animal was allowed a daily run in the dog-yard attached to the kennels. The second operation was carried out under anæsthesia produced by chloroform-ether mixture. The skull was trephined and the dura incised in the usual manner. Stimulation was carried out with ordinary double electrodes connected with the secondary coil of an inductorium. When the stimulation experiments, central and peripheral, were completed, the dog was killed by chloroform injection without any intermission of the anæsthesia having taken place.

Experimental.

Experiment I.—A female terrier, about 6 months old, was operated on. The *left* middle brachial cord was divided and its proximal stump brought under the trachea and sutured without tension to the distal end of the divided right middle cord. The proximal stump on the right side was drawn into a rubber tube and tied with silk to prevent regenerative sprouting. When the animal was examined, ten months later, co-ordination was found to be very good. The dog could walk and run naturally, and use either forepaw to hold down a bone. The stimulation experiment was carried out 308 days after the primary operation.

Stimulation in the right motor cortical area gave movement of both fore-limbs—namely, (*a*) extension of paw and flexion of elbow in the left (contralateral) fore-limb; (*b*) contraction of triceps and feeble contraction of paw extensors in the right (ipsilateral) fore-limb.

Stimulation in the left motor cortical area gave no movement of the ipsilateral fore-limb, but elicited various movements of the contralateral fore-limb, excluding contraction of triceps and paw extensors.

The peripheral nerves affected were exposed. The left middle brachial cord was found passing behind the trachea, and in regenerative union with the right middle cord. There were no irregular unions detectable, and the remains of the proximal stump of the right middle cord were found in the rubber tube, which was bleached but intact. The left middle cord was divided, and its distal end stimulated (of course proximal to the point of suture). Such stimulation gave movements in the right fore-limb only; the movements were confined to the triceps and paw extensors, and were similar in every respect to those elicited by ipsilateral cortical stimulation.

Experiment II.—A male terrier, about 9 months old, was operated on. Here an attempt was made to suture the left middle brachial cord to the whole of the right brachial plexus, but, as subsequent dissection showed, only the upper part of the right plexus was enclosed in the suture.

When examined nearly ten months afterwards the co-ordination was good. The stimulation experiment was carried out 301 days after the primary operation.

Stimulation in the right motor cortical area gave movement of both fore-limbs—namely, (*a*) headward movement of the limb, with strong extension in the left (contralateral) fore-limb; (*b*) elbow flexion and contraction of the shoulder muscles, particularly the deltoid, on the right side (ipsilateral).

Stimulation in the left motor cortical area gave no ipsilateral movement, but elicited movements of the contralateral fore-limb in which elbow flexion preponderated.

The peripheral nerves affected were exposed by dissection. The left middle cord was found passing behind the trachea. It was then cut proximal to the nerve suture and its distal end stimulated. Such stimulation gave no movement on the left side, but gave vigorous movement in the right fore-limb similar to that given by ipsilateral cortical stimulation.[1]

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[1] In a third experiment the primary operation was similar to that in Experiment I. Unfortunately, in the stimulation experiment, six months later, the longitudinal sinus was opened and, owing, doubtless, to the severe hæmorrhage that ensued, we were unable to obtain movements of any limb in response to cortical stimulation.

Discussion of Results.

Our experiments, therefore, are in full accordance with those of Kennedy. They demonstrate (to use Kennedy's language) that an interchange of function can readily occur in the motor centres of the cerebral cortex. If attention be confined to the connexion between the cortex and the motor apparatus in the cord, we may state that here there is morphological fixity, but functional lability.

The older view that the pyramidal fibres make direct synaptic union with the motor cells of the ventral cornua is gradually being replaced by the idea that the pyramidal impulses enter the cord motor apparatus more on the sensory side. In the performance of a skilled movement certain reflexes must be inhibited, and this can be most economically performed, not by damping the individual motor neurons, but by throwing resistance into each reflex apparatus (or "draining" it) where there is greatest convergence of the appropriate reflex axes. But in the performance of an unrehearsed action it is also necessary to postulate that the cortex, if it does not play upon individual muscles, acts at least through the simplest co-ordinating mechanism—namely, that which produces a definite movement in a joint. This view is certainly borne out by Kennedy's and our experiments. Here the conducting paths remained unaltered from the cortex right down to the point of suture in the peripheral nerve-trunk, and yet co-ordination was acquired[1] [2].

We are justified, too, in assuming that in these experiments a considerable number of the sensory impressions from the affected limb, both integumental and proprioceptive, were projected on a wholly new cortical field, and yet these could apparently be used in guiding the discharges from the motor zone. Doubtless visual perceptions were used largely in the new co-ordination. In Kennedy's dogs, where flexor and extensor nerves were interchanged, visual guidance operated much in the same way as in the case of the microscopist who speedily learns to produce without conscious analysis a left-to-right movement of the magnified image by a right-to-left movement of the slide. In the dogs in our own experiments the whole sensory field had its normal cortical connexions except the two fore-limbs, one being fractionally apæsthetic. When a false movement is made the whole body participates and the stream of afferents from retina, labyrinth, and body proprioceptors, after a number of repetitions, will compel the animal to abandon that particular motor grouping, normal as it may be at its cortical centre, and to become experimental in its movements. To assume that the new co-ordination is effected by known neurological mechanisms is surely safer than to postulate a supra-cortical control.

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[1] In Kennedy's case of union of the facial with the spinal accessory the lack of co-ordination, shown by the associated and synchronous movements of the shoulder and face, is easily explicable on the assumption of axon bifurcation. In this case the proximal spinal accessory was sutured to the distal spinal accessory and facial, giving the multiple path which we have shown to be favourable to axon-dichotomy.

The expenses of this research were defrayed in part by a grant to one of us (W. A. O.) from the Science Committee of the British Medical Association, and in part by a grant to one of us (B. K.) from the Government Grant Committee of the Royal Society.

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PUBLICATIONS RECENTLY RECEIVED.

[*Notes on a book under this heading do not preclude a subsequent review.*]

The Optic Nerve and the Accessory Sinuses of the Nose. By Professor A. ONODI. Authorized translation by J. LÜCKHOFF, M.D., with 50 illustrations. Pp. 101. London: Baillière, Tindall and Cox, 1910.

The first sixty-eight pages of this careful monograph deal completely with the anatomical relations of the accessory sinuses of the nose to the optic nerve. All the varieties that may occur are carefully described and excellently illustrated. The second half is devoted to clinical facts bearing on the production of optic neuritis and atrophy from suppuration of the sinuses or injury to their walls by fractures or other lesions. The book treats a difficult subject with clearness and is based on first-hand observation. It is well translated and the illustrations are unusually good.

Three Lectures on Epilepsy, being the Morison Lectures delivered before the Royal College of Physicians of Edinburgh in 1910. By WILLIAM ALDREN TURNER, M.D., F.R.C.P. Pp. 62. Edinburgh: Mackenzie, 1910.

The author devotes the first of these lectures to the manifestations of epilepsy, its predisposing causes, and the nature of the epileptic patient. After considering toxæmia as a cause of epilepsy, he passes on to a lecture on the border-line of the disease, and discusses the relation of epilepsy and hysteria, epileptoid phenomena, and such sleep symptoms as night terrors in the adult. The third lecture is devoted to treatment, and the advice given is succinct and excellent. This work can be recommended to all practitioners anxious to obtain in small compass a knowledge of the main facts of epilepsy and its treatment.

L'Aphasie dans ses rapports avec la démence et les vésanies. Avec cinq planches et quatre figures dans le texte. Pp. 253. Paris: Steinheil, 1910.

The greater part of this monograph is devoted to a consideration of the mental state of patients with aphasia. Marie holds that every case of aphasia shows diminished intelligence, though this diminution in no way corresponds with a dementia. The author states that in some cases the intelligence is untouched, but that some cases of aphasia are true organic dements. This dementia is due to lesions other than that causing the aphasia. Fifty-two cases are considered in varying detail.

Nouveau Traité de Médecine et de Thérapeutique. [GILBERT et THOINOT.] XXI Sémiologie Nerveuse. Par ACHARD, MARIE, GILBERT BALLET, LÉVI, LÉRI, LAIGNEL-LAVARTINE. Avec 129 figures intercalées dans le texte. Pp. 629. Paris: Baillière, 1910.

This volume of the "Traité de Médecine" deals with grouped signs of nervous disease. Thus, apoplexy, aphasia, hemiplegia, paraplegia, delirium, convulsions are treated in separate chapters by different writers. Contracture, tremor, vertigo, headache, trophic and secretory troubles are all fully dealt with. Such an arrangement is unusual in English text-books, but is excellently carried out. The question of the causes of aphasia is discussed with admirable clearness and completeness. The volume is well illustrated, and the only fault in arrangement is the absence of an index.

Surgery of the Brain and Spinal Cord, based on Personal Experiences. By Professor FEDOR KRAUSE. Translated by Professor HERMAN A. HAUBOLD. Vol. I, with 63 figures in the text, 24 coloured plates, and one half-tone plate. Pp. 282. London: H. K. Lewis, 1910.

This is a translation of the first part of Professor Krause's admirable book on brain surgery, a work of great interest from the fact that it is a record of personal experience. All the principal methods of attacking various portions of the brain are given, and are illustrated with lithographic plates. The English is slipshod and careless.

Organic and Functional Nervous Diseases: a Text-book of Neurology. By M. ALLEN STARR, M.D., &c. Third edition, thoroughly revised. Illustrated with 300 engravings in the text and 29 plates. Pp. 911. London: Baillière, Tindall and Cox, 1910.

This text-book is already well known, and much new matter has been added in the present edition. It is fully illustrated, but some of the photographs of the spinal cord might be lettered for the sake of the student unfamiliar with spinal topography. The results of the author's own researches are given clearly and fully, especially in the chapter on Spinal Segmentation.

Writers of "Original Articles and Clinical Cases" are supplied free of charge with 50 copies reprinted in the form in which the paper stands in the pages of "Brain." If reprints are required in pamphlet form, with wrapper, title-page, &c., and re-numbered pages, they must be ordered, at the expense of the writers, from Messrs. BALE, SONS & DANIELSSON, Ltd., 83-91, Great Titchfield Street, London, W.

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EDITOR.

[JANUARY, 1911.]

BRAIN.

PART III., 1910.

Original Articles and Clinical Cases.

TWO THEORIES OF HYSTERIA.[1]

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GENTLEMEN,—It is first of all my duty, and a most pleasant duty it is, to thank you for the very great honour you have done me by electing me to be your President for the coming year, and to assure you of the pride and pleasure I feel in being allowed to preside over your work, and of my earnest wish to help it forward, so far as in me lies.

But there must be always a fly in the amber and a thorn in the rose; and the thorn to me has been this address. For it is a disappointment to me to feel myself unable to put before you some new and original piece of work, as so many of my predecessors have done. I recall that on the very subject I have chosen—hysteria—addresses of this kind have been given you by Dr. Thomas Buzzard and Dr. Sharkey. But I am obliged to forego the ambition to be original; and in lieu thereof, I ask your attention while I endeavour to sketch out two striking theories on the subject of hysteria—first that of Professor Pierre Janet, of Paris; secondly, that of Dr. Breuer and Professor Freud, of Vienna. There are some of you, I know, who have already studied these theories in detail: from them I must simply ask indulgence; there may be others whose attention has not yet been turned this way, and perhaps they may find what I have to say sufficiently novel to be interesting.

I shall not attempt to give you a history of all the theories that have been held about hysteria—interesting subject though that might be—but I shall merely remark that you may find underlying most of them two different drifts of thought, which have only within comparatively recent times become distinctly differentiated. The one seeks to explain the disease on a physical or bodily basis, the other on a psychological. Even the old writers who held the frankly material view that hysteria was due to the wanderings of the womb round the body, like those of a lion round its cage, freely emphasized the mental peculiarities of the patient, though the term "vapours" furnished a convenient physical explanation of these also. Briquet, who led the way in the modern study of hysteria, speaks very cautiously. To him, as to many still, emotion was the keynote of the disease, but he says "hysteria is a disease of that part of the brain which subserves the emotions." Since his time the trend has been more and more towards the psychological explanation of the disease, in spite of the gallant attempts, if I may so call them, of Dr. Bastian and of the late Dr. Savill to put it on a physical basis. Paget spoke of "neuromimesis" and of want of will, Russell Reynolds of paralysis from idea, Möbius declared that the disease was "ideogenous." But none of these suggestions carried us very far; first, because they failed to cover the whole ground, secondly, because a patient could have replied, with perfect truth, "I make the effort of will as much as ever I did. I know nothing about the diseases you suppose me to copy; and before I was paralyzed, no notion of paralysis had ever occurred to me." So the psychologists had to take a wider ground, and this they did most effectually when they included in their theory subconscious mental operations, and the notion, arising out of them, of dissociation of the personality.

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[1] Presidential Address before the Neurological Section of the Royal Society of Medicine.

Since these conceptions underlie both the theories I shall deal with, something must be said, however briefly, about them first. It seems that there are two classes of mental phenomena; one which at first sight hardly seems to deserve the name "mental," because they are facts of which we take no personal cognizance. Yet it is certain that impressions of all kinds pour in upon us from the organs of our body and from the outside world and that memories and ideas of the past are constantly rising up within us, of which we have no personal consciousness: that they affect us, that they group and associate themselves just as do our conscious thoughts, and that, under some circumstances, they may emerge into the light of consciousness, though we never before knew them to exist. These are called subconscious ideas, the workings of the subconscious mind—a phrase which is becoming dangerously popular, since we hear it nowadays from the pulpit and from the daily Press. The other class are just ordinary mental phenomena, the perceptions, feelings, and thoughts of our daily life, which are known to our conscious personal selves, and which, perhaps, seem to need no further explanation. Yet what is this self, this personality, which consciously feels and thinks?

According to Janet, it is the vast system of ideas which has been growing up all our lives by continuous perception, storage, and grouping of mental facts into a systematic whole. Each time that a new mental fact, however simple or complicated, or the memory of an old one, is brought into relation with this system and relegated to its place therein—assimilated, to put it shortly—an act of consciousness takes place. Thus the personality grows, becoming daily a more complicated yet more individualized mosaic, as the individual experiences are fitted in.

When did this process begin? What was the birth of this self? I do not know the answer of modern psychology. Aristotle, if I remember rightly, said that the soul did not enter the body till after the first years of life. And so says a modern poet:—

"The baby new to earth and sky,
What time his tender palm is prest
Against the circle of the breast,
Has never thought that 'this is I.'"

But another one says:—

"The soul that cometh with us, our life's star,
Hath had elsewhere its setting,
And cometh from afar."

But I am digressing: we must return to the subconscious. Just as our recognized perceptions, our conscious mental states, become assimilated to the system which we call our personal self, so (it is said) may our subconscious mental states, of which we are not cognizant, group themselves into systems of their own. Indeed, this may go on to such an extent that in certain instances there may grow up a second self, independent of our known self. This process is called the dissociation of our personality.

Now, though our subconscious mental life and the secondary states that may arise therein play a most important part in hysteria, nevertheless that which, according to Janet, is really distinctive of the disease is what he calls the restriction of the field of personal consciousness.

This may be explained as follows: The normal mind can perceive—that is, take in and arrange—many things at once, whether these be sensation, memories, or more complicated mental states, such as emotions or abstract ideas. This comprehensiveness of perception may be called the field of consciousness. The hysterical mind can take in much less. The multiple sensations are there: they reach the subconscious mind (as can be shown in various ways), but they are not assimilated to the system which is called the personal consciousness. As an example is taken hysterical restriction of the field of vision. A normal person, besides seeing the object fixed by him, is conscious of objects at the periphery; an hysterical patient very often is not.

At the risk of being a little tedious, I must now try to follow out this theory through some of the symptoms of hysteria, making first this assumption: that in proportion as the field of personal consciousness diminishes, so do the subconscious mental conditions tend to flourish and abound. In this way is accounted for the prevalence and importance of these secondary states in hysteria.

It is natural to begin with some of the mental manifestations of the disease.

Owing to the particular disability which has just been mentioned the patient may become unable to combine certain memories of the past with the perceptions of the present. He then exhibits hysterical loss of memory—amnesia. Strange instances of gaps in the memory are related by Charcot, Janet, and other French authors. We hear less of them in this country; still, they occur. Thus a girl was under my charge at St. Bartholomew's, about a year ago, with hysterical paralysis. On questioning her as to the circumstances under which it arose, I found she had entirely forgotten some months of her life at that time. Neither the girl nor her mother had said anything about this loss of memory, so it was found out by chance. Another patient, after falling off a bicycle without apparently sustaining any serious injury, did not know who he was or where he was, or even that he was married, until his wife arrived to remind him.

Short of such a complete blotting out of memories, it is obvious that a person who can only bring together a limited number of ideas at once is less checked and governed by past experiences than a normal person, and thus lays herself open to the charge of fickleness and insincerity, whereas she really suffers from a species of forgetfulness. Again, since she can take no comprehensive view of facts and motives, being only able to realize them piecemeal, as it were, reasoned volition becomes replaced by impulsiveness, and she is said to suffer from weakness of will.

Further (and this seems to be of great importance), when a particular idea is placed prominently before such a patient's mind, there is lacking the restraining and modifying influence due to the simultaneous presence of other ideas and counter-experiences. Thus the one idea acquires undue importance and tends to reign supreme over the thoughts and conduct. Hence the importance of the fixed idea in hysteria, and the power of suggestion when an idea is forced on such a patient by another person.

This untrammelled force of a single idea might very well be used as an explanation of the emotional character of such patients. It might be argued that the emotional reaction is violent, because the stimulus is untempered. Janet, however, takes a different view. An emotion, he says (following herein William James), is a very complicated mental state, requiring the combination of a great many mental phenomena. But this is just what the hysterical patient cannot do. Hence she is not emotional, in the sense of readily responding with conscious emotion to the circumstances of the present. The emotions she exhibits are really old ones, relating to circumstances of the past, which have become automatic—old tunes, played in her subconscious mind, as if on a barrel-organ.

I doubt whether this view will commend itself to everybody. But, to tell the truth, the mental and moral symptoms of hysteria are a little vague. Let us therefore turn to the more definite physical symptoms.

An hysterical fit is held to be an attack of somnambulism. There are two elements in it: First, amnesia; for all the facts of the patient's real life pass out of her mind, and she takes no notice of her surroundings, except so far as they can be made to enter into her dream. But (secondly) her mind is not empty, it is possessed with some idea or scene of the past—usually those circumstances which led up to the first fit. In the most typical fit these circumstances are acted out in detail by pantomime or speech. All this is forgotten as soon as the fit passes off; but recurs with the same manifestations when the next fit comes. So that we may distinguish two factors—(*a*) the alternating amnesia, and (*β*) the dominating idea with its appropriate histrionic setting. In such cases we can hardly speak of restriction of the personal consciousness; for during the fit the personal consciousness has disappeared, and something else reigns in its stead.

The full-blown fit of this type appears to be commoner in France than in England. It may be that the English patient lacks the dramatic instinct. Anyhow, her performance, if such it be, is far less intelligible to the onlookers and gives much less clue to her thoughts. The fits we see here are generally of the hysteroid type, in which meaningless struggles, rigidity, and opisthotonus play a large part; or the popular "fit of hysterics," such as a "globus" followed by an emotional display, apparently without loss of consciousness. It is rather difficult to explain these as a scene from the past, unless we suppose that the past of very various patients has been very much the same. I should like, however, to mention here an instance of the dramatic style of fit, the appearance of which made an important difference to the diagnosis of the case. A young sailor was sent into Queen Square Hospital with the following history: In the course of a gun-drill an explosion had happened, and a piece of flying metal had struck him on the head and rendered him unconscious. Ever since he had been subject to fits, characterized (we were told) by unilateral convulsions. It was peculiar, however, that the convulsions were on the same side as the injury to the head. Nothing happened in the hospital till the day when he was going out. Then he had a fit (witnessed by the resident officer) in which the whole scene of the gun-drill was re-enacted. He listened for the word of the commanding officer, made the proper reply, went through the manipulations of the gun, and finally, presumably when the explosion happened, fell down unconscious. Up to that time the question had been whether he might not have some local injury to the brain, for which he ought to be trephined.

Hysterical anæsthesia, the most important of Charcot's "stigmata" of the disease, is thus explained on Janet's hypothesis of a restricted field of personal consciousness. Suppose that a patient can consciously perceive only a small number of sensations at once; it follows that he must cease to attend to some sensations, and such failure of attention may become habitual, till at last the conscious perception of them ceases entirely—*i.e.*, he becomes anæsthetic. Whether this be the exact process or no, a psychical rather than a physical explanation of hysterical anæsthesia really seems necessary. For, firstly, the distribution of such anæsthesia is not determined by anatomical conditions, such as the distribution of nerves, or nerve roots, or blood vessels, but rather by the patient's own conception of his hand, arm, leg, or whatever the anæsthetic part may be. Secondly, the anæsthesia is physically unreal. Even in cases where it is most intense (nay, perhaps most easily in such cases) it can often be shown that sensations still reach the patient; that he feels, though he thinks that he does not feel. Thirdly, the discovery of anæsthesia often comes to him as a surprise: he did not know of it before he was medically examined. On the strength of this last fact, indeed, Babinski maintains that the anæsthesia is the result of suggestion, put there, in point of fact, by the physician. This may be true for some cases, but certainly not for all, nor even, I think, for most cases.

Now anæsthesia, which we commonly regard in the light of its geographical distribution over the body, really leads up to a more difficult and general question. This lack of personal perception may be "systematized." This is best seen perhaps in amnesia, or forgetfulness, which is really only an inability to revive perceptions of the past in consciousness. Such forgetfulness may centre round a particular event or a particular person; everything else is remembered, but all connected with that event or person is forgotten. There may be similar gaps in the perception of present things. Perhaps this latter is most often seen in artificial hypnosis; the hypnotized subject hears and obeys the voice of his charmer, but not that of others, and he can be rendered blind to a particular object, while he sees everything else. Still, the same sort of thing occurs in hysterical somnambulism. But, it is added (and this gives to the theory a very general significance), hysterical disabilities may centre, not merely around this or that person, or thing, or district of the body, but also round particular bodily functions. We must consider here for a moment what a bodily function means. To the physiologist it is an organized grouping of physical events, muscular contractions, secretions of cells, reception, transmission, and arrangement of nervous impulses, and so forth. Some of these groups, let us say those of cardiac action or respiratory movements, are so thoroughly organized that they seem to be completely automatic and to have no mental correlation. Doubtless they once had, perhaps they still have; but, at any rate, it is unimportant. But it is quite otherwise with less organized functions, such as speech, writing, vision, hearing, &c. In correspondence with these, which are being continually developed to meet the continuous demand of new circumstances in which they have to be exercised, there is a vast amount of psychological construction still going on. Mental facts of all kinds connected with their exercise, sensations, volitions, emotions, memories, &c., are being built up into a system corresponding to the function—into the idea of it, if you like. This is the function from the psychologist's point of view, and upon this, according to Janet, the hysterical ban may fall.

This digression was necessary before we consider the explanation of hysterical motor paralysis. There may be several varieties of this. A patient may lose all sensation in a limb, including the sense of position; in such a case she can only move the limb when she looks at it (Lasègue's phenomenon). If, in addition, she has lost the memories of movement, she will be unable to move at all. There was a child in Queen Square lately who, after some acute illness, had hysterical paraplegia. When asked what had caused the paralysis, she replied with perfect truth, "I was in bed too long." She had forgotten the use of her legs.

Again, paralysis may be due, as has been said, to idea. The patient has adopted a disabling suggestion that she cannot, or ought not to, move, and forthwith she becomes unable to do so. The idea may be subconscious, the patient not knowing of its existence or of the relation of the paralysis to it. Lastly, there remains the condition where paralysis seems to affect a function rather than a particular part of the body. The grasp of the patient's consciousness is so limited that she cannot make the combination of mental activities requisite for the exercise of a particular function. The condition called astasia-abasia is an example of this. The muscles of the legs are strong, the reflexes normal, there is no anæsthesia, the movements of the legs when lying down or sitting are perfect; only, the patient can neither walk nor stand. She is paralyzed for those actions, and those only. Nay, the specialization may go further. I remember a lady who could walk quite well in the house, but who could only walk out of doors when she knew some one was by her side. If some one did, she could walk quite well and without support. In such a case the structures necessary for the function are sound; nay, the function itself can be performed, but only under special circumstances. It will be said that is mere nervousness; but, then, what do we mean by "nervousness"?

The idea of a function as a kind of nervous entity is pushed farther (perhaps you will think too far) to explain certain motor disturbances which are characterized by agitation rather than paralysis. Thus, as mutism is the paralysis of speech, so it is said there is a condition of logorrhœa, a deluge of inconsequent talk, in which speech seemed to have freed itself from personal control and exercises itself automatically. It is hinted that hysterical chorea and involuntary movements may sometimes be of this character. But probably most of these latter are due to a fixed idea. Janet gives this instance:—

A man, ever since an attack of typhoid, had the habit of making an odd grimace, ending with a noisy expiration through one nostril. This was due to the unconscious idea that he had caked secretion in the nostril, as indeed he had had at one time. He was cured by a counter-suggestion. I may remark that ideas seem readily to fix themselves on the nose. A governess used to come to the out-patient room at Queen Square complaining of "nervousness," which, she said, had lost her several situations. One day, finding me alone, she told me what the nervousness was. She said, "Can you tell me whether there is a passage from the eye to the nose big enough to get my little finger down? I can't get rid of the idea that there ought to be." I drew her a diagram of the lachrymal duct, enlarging the size a little to meet her requirements; and she went away saying, "Thank you so much; now I feel that I shall be much better." But I never heard whether she was.

I shall only touch on one more out of the long gamut of hysterical symptoms—namely, localized pain, and, what is still commoner, localized tenderness. These symptoms, apparently physical, are to the psychologist expressions of a fixed idea, generally subconscious, and often connected with the shock that first called the hysteria into active existence. Examples :—

(1) From Janet ("Les Nevroses," p. 171): A man hurt his shoulder in a lift accident. Long after the injury was cured there remained a tender point; when this point was touched he had spasm in the shoulder muscles, a feeling of terror, and a sense of suffocation.

(2) A woman came to Queen Square for trigeminal neuralgia. An operation for the removal of the ganglion had been already performed; a second, and finally a third one was performed. Thus the surgical treatment was certainly sufficiently complete; yet relief was only temporary, the local pains returned, and with them she developed a peculiar mental state and a left hemianæsthesia, undoubtedly hysterical. It was curious to see in the same patient an hysterical hemianæsthesia and an organic anæsthesia in the district of the trigeminus.

(3) From Janet (*ibid.*) : A girl had shiverings and horrible feelings whenever her right side was touched. For this she could give no reason, but finally she had an attack of somnambulism, during which it was ascertained that she had once had a dream in which she fancied that a man lay by her right side and attempted to assault her.

So in these three cases the fixed idea originated from an injury, from previous disease, and from a dream respectively

How does hysteria, then, differ from the allied complaint commonly called neurasthenia, or more properly psychasthenia, in which also fixed ideas play so large a part? The psychasthenic does not suffer from the disability characteristic of hysteria—*i.e.*, the inability to bring within range of his personal consciousness more than a few facts at once; hence he retains the appreciation of his fixed idea along with that of his personal life. It has not dropped completely into his subconsciousness. Thus it is more under his cognizance and control, but it torments him more. The hysterical patient, on the other hand, is liable to alternations of mental state—one, the paroxysm in which his personal consciousness is in abeyance, and the fixed idea, unchecked by realities, holds complete sway; the other (the interparoxysmal state) in which he is unconscious of the fixed idea, which, nevertheless, may be there, and producing some paralysis or other permanent symptom.

An elaborate comparison and contrast between the symptoms of hysteria and psychasthenia is given by Janet in his book on the neuroses. How does the hysterical state differ from that of hypnosis? The answer is that there is no essential difference. Hypnotism is somnambulism artificially produced; and the peculiar relation of the subject to the hypnotizer is produced solely by the gradual introduction into the patient's mind of the idea of the operator's personality, and this, like other fixed ideas, soon comes to dominate his whole mental state. That hypnosis is at bottom hysterical is shown by several facts, such as (1) the similarity of symptoms; (2) that the resemblances of previous hysterical states can be revived by hypnosis; (3) that none but hysterical subjects are hypnotizable. But this last statement is certainly not admitted by all authorities.

I must now turn to the theories of the other two authors I proposed to discuss—Breuer and Freud. It seems that their earliest papers were written conjointly, and are more concerned with the explanation of certain hysterical phenomena than with an exposition of the essence of the disease. On this latter point Freud has given his views in later papers more fully. Their theories are closely connected with, one might almost say founded upon, a special method of treatment.

Starting with the facts of traumatic hysteria, as described by Charcot, they regard hysteria in general as a kind of psychical trauma. The patient receives some mental shock which, instead of passing off by degrees, remains buried in his consciousness, or rather subconsciousness, as a foreign body might remain in a wound, and constituting a permanent source of irritation, which is manifested by hysterical symptoms. The treatment, to carry their own metaphor a little further, may be compared to opening up the wound and removing the foreign body.

Leaving metaphor, the broad outline of the theory is as follows: Every event that appeals to our emotions, and particularly to painful emotions, such as fear, anger, sorrow, &c., raises in the mind a disturbance, stress, and strain which they call the "affect"; this latter generally finds an appropriate outlet, as in an act of retaliation, or, perhaps, merely in tears or language; this process they call "abreagirung." In English we speak of giving vent to pent-up feelings, or, in common parlance, of "working them off," or "blowing off steam." But whatever name be used, the fact is well known that by outward expression of the feelings the mental tension is relieved:—

> "Home they brought her warrior dead,
> She nor swooned nor uttered cry;
> All her maidens, watching, said,
> She must weep or she will die."

Only, according to Breuer and Freud, she will not die, but become hysterical.

But how or why should she?

If her distress expended itself in tears, the next time that scene recurred to her the mental tension would be less, probably she would weep again, and that, again, as the saying goes, would do her good; till finally the memory would become sad, no doubt, but bearable—"the idea would be shorn of its affect." That is one principle, that complete and appropriate expression of feeling robs the idea of its emotional effect.

But if she cannot weep, what then? Either the course of time, the wear and tear of her future life, the calmer feelings that she can bring to bear upon that memory, or perhaps some skilfully contrived counter-association, like that contrived by the nurse who "slipped her child upon her knee," will gradually bring relief; or else a process may take place which Breuer and Freud call "conversion of the affect," and which they regard as lying at the root of most hysterical symptoms.

This is as follows:—

The unbearable memory cannot be annulled; but the patient banishes it from consciousness. That is, however, a *pis-aller*. "Naturam expellas furcâ, tamen usque recurrat." For the idea remains in the lower strata of the mind, the subconsciousness, whence it crops up from time to time, like a submerged rock at low tides, unrecognized, it is true, by the patient, but yet producing the same mental distress as at first. This distress must be relieved, and it is relieved by providing some physical and bodily occurrence to take its place. How this can be done we do not know; but assuming that it can be done, that such a substitution of physical for mental can be made, it is obvious that the act will grow easier with repetition, till finally it becomes automatic. So now the patient, having banished the original idea from his mind and substituted a symptom for the mental "affect," may know nothing of the meaning of this symptom, which to him and to his friends appears to be a new disease, instead of being the effect of an old memory.

The process then involves two steps. First step: The patient by an effort of will forcibly represses the idea which is troublesome to him. How this is done we do not know, but it is very justly pointed out that just as we can voluntarily concentrate our attention on an idea, so probably we can voluntarily withdraw it. Some childish talk may illustrate this. A little girl was afraid to go up some dark stairs, because she thought of a wolf there. A little brother's advice was "Don't think of the wolf, think of something nice: think of those cakes." And she successfully did so. Second step: "Conversion of the affect," substitution of a bodily phenomenon for the mental distress. This process we do not understand at all. Perhaps we may call it an extension of the principle with which we began—namely, that appropriate expression of emotion tends to relief. Only, in this case the expression often seems singularly inappropriate. Take examples: Why should disappointment in love find expression in the smell of a cigar? Why should hyper-algesia of the thigh follow the nursing of a patient with heart disease? Why should facial neuralgia follow an insult from a husband? The answers to such questions open a fine field for guesswork. The association may be due to mere coincidence in time. Thus the lady who smells the cigar had a shock from the conduct of her supposed lover while he and others were smoking. She was also suffering from a chronic affection of the nose, so perhaps the symptoms attached itself to a point of least resistance. The lady with the hyper-algesia of the thigh used to rest her father's œdematous leg on her thigh while she bandaged him. The lady with facial neuralgia deals in symbols. When her husband insulted her she thought (consciously or otherwise) "that was a slap in the face," and the neuralgia came. Or there may be, it is suggested, deep and old associations, common to the race, which we can hardly hope to trace out. Perhaps opisthotonus and other fundamental hysterical symptoms may be the expression of these. In this connexion

I recall a case of hysterical mutism where, in spite of terrible efforts, the patient could not utter a sound. After several weeks in response to these efforts there came a voice so harsh and strained that the whole ward wished the patient was dumb again. Now, which of us has not experienced in dreams this painful and fruitless effort to speak, which generally culminates in an inarticulate cry, and the remark from some one close by, "What *is* the matter with you?" Or if this be thought too trivial, let us recall Virgil's description of emotion: "Obstupui, steteruntque comæ et vox faucibus hæsit." And "dumbfoundered," "struck dumb," are good English expressions.

Now if I have dwelt on this process of "conversion," it is because Breuer and Freud assure us that the power of exercising it—the power, that is, of replacing mental distress by some apparently inappropriate bodily phenomenon—is a special characteristic of hysteria. It may happen otherwise: the distressing idea may be repressed, but the distress itself remain, not having been "converted." Then there results (they say) not hysteria, but a more obviously mental neurosis, such as "phobias" and "obsessions."

The voluntary repression of the distressful idea, the banishment of it into the realm of subconsciousness, is the same in both cases. Hence both hysteria and these same phobias and obsessions are called by Freud "defence-neuroses." But he recognizes (or, at any rate, his colleague Breuer does) another process by which hysterical symptoms may arise. In this second process the original tormenting idea is never present to the consciousness at all. It has arisen while the patient was in a peculiar frame of mind which they call a "hypnoid state." The hypnoid state is a sort of absent-mindedness—not, indeed, the absent-mindedness which is produced by active concentration of thought, as in the solution of a problem or the following out of some difficult train of thought; but rather a kind of daydream wherein the thoughts are unaffected by the present or past events of real life, and are unchecked by self-criticism. To be sure, we cannot call every one who indulges in reveries, or builds pleasant castles in the air, mentally abnormal, but there is just the risk that something pathological may develop out of this—viz., the leading of a second imaginary life apart from his own, the beginnings of a dissociation in his personality. In this pathological state ideas may develop which remain out of all relation to the current of his normal ideas, and finally establish themselves as hysterical fixed ideas, the sinister results of which we have already seen.

Now the soil on which such hypnoid states grow seems to be mental isolation amid depressing circumstances or remembrances, such as the atmosphere of the sick chamber of some dear relation, the brooding over misfortunes or injustice; in short, "chewing the cud of melancholy." One emotion indeed—namely, terror—is credited with producing such a state suddenly and at once. Even animals may be fascinated with fear. Most of us could give instances. I remember one which impressed me much in my boyhood. In those days there was a single railway-line between Norwich and Yarmouth. Upon this line, near Norwich, two trains going in opposite directions collided, with very terrible results. A certain person, of whom I had often heard, was in the rear of the train going towards Norwich. He was not injured, but walked at once (so I heard) past the scene of the accident into Norwich, where he said nothing of what happened, and afterwards, when questioned, said he did not know there had been an accident. Of course kindly critics said that he had neglected the duty of giving help, that he was a coward, and also a liar. But I suppose he was so profoundly affected that he really did not know. What happened to him afterwards I never heard; but there were all the materials ready for a traumatic hysteria.

These, then, are the two principal ways in which, according to these authors, hysteria may originate—either as a defence-neurosis, where the idea has been forcibly relegated to the subconsciousness; or as a hypnoid hysteria, where it has always been there. A third possibility seems to be that the idea may not be banished, but that, through want of a proper vent to the emotional disturbance it sets up, hysteria develops. This would be, I suppose, what they call a simple "retention hysteria." But neither of them lays much stress on this, and indeed Freud seems to think that the first-named process—namely, the defence hysteria—is the only one of capital interest.

I ought, perhaps, to say something here about Freud's method of treating hysteria, called "psycho-analysis," which professes, as I understand, to be not merely a method of treatment, but also the means of eliciting facts on which the theory is based. The principle of it, as I have already said, is to bring the troublesome idea into the light of personal consciousness, and to allow the mental distress which it then produces to have a complete vent, say, in tears or in speech; and when this is done the hysterical symptoms (it is averred) will disappear. The idea, being the forgotten memory of some past event, or scene, or feeling, can only be discovered by gradually directing the patient's thoughts into such channels as may lead back to it, and it goes without saying that this may be a most difficult, delicate, and (I should imagine) unsatisfactory process.

The original practice was to hypnotize the patient. But this, owing to the difficulties presented by many patients, was abandoned; and instead of it, the patient was placed in a recumbent position, with the eyes closed, and told to concentrate her attention on the memories of her past life. If appropriate memories refused to come, pressure was made by the physician's hand on the patient's head, coupled with the assurances that such memories must and will come. The process of directing them and eliciting them is carried on until the crucial memory was reached. Nay, more, they might have to be forced upon the patient (this is Freud's own expression), because the revival of them is disagreeable, just in proportion to the original effort made to banish them.

As may easily be imagined, the pressure on the head has, in turn, been given up; and I understand that the method now employed is as follows (I quote from Brill's preface to a translation of some of Freud's papers) :—

"The patient lies on his back on a lounge, the physician sitting behind the patient's head at the head of the lounge. In this way the patient remains free from all external influences and impressions. The object is to avoid all muscular exertion and distraction, thus allowing thorough concentration of attention on the patient's own psychic activities. The patient is then asked to give a detailed account of his troubles, after having been told before to repeat everything that occurs to his mind, even such thoughts as may cause him embarrassment or mortification. On listening to such a history one invariably notices many memory gaps, both in reference to time and causal relations. These the patient is urged to fill in by concentration of attention on the subject in question, and by repeating all the unintentional thoughts originating in this connexion. This is the so-called method of free association. The patient is required to relate all his thoughts in the order of their sequence, even if they seem irrelevant to him. He must do away with all critique and remain perfectly passive. It is in this way that we fathom the original meaning of his symptom. But as the thoughts which originate in this way are of a disagreeable and painful nature, they are pushed back with the greatest resistance. This is further enhanced by the fact that the hysterical symptom is the symbolic expression of the realization of a repressed wish, and serves as a gratification for the patient. He strives very hard—unconsciously, of course—to retain the symptom, as it is the only thing left to him from his former unattainable conscious wishings and strivings. The object of the psycho-analytic treatment is to overcome all these resistances and to reconduct to the patient's consciousness the thoughts underlying the symptoms. Here lies the greatest difficulty, for, just as in the normal life and the dream, a psycho-neurotic symptom is merely a symbolic or cryptic expression of the original repressed thoughts. . . . . To discover the hidden mechanism, one must make use of the author's developed method of interpretation—that is, one must look for symbolic actions, lapses in speech, memory, &c.; and above all, one must resort to the analysis of dreams, as they give the most direct access to the unconscious."

It remains to notice those later developments of Freud's theories which are of the highest importance, *if true.* Concerning these I must be very brief.

What is the nature of the tormenting ideas which the patient has repressed, and when emotional "affect" has been "converted" into hysterical symptoms? The answer is that they are always of a sexual nature. The ground of this assertion seems mainly to be that in all hysterical cases which Freud has submitted to his process of psycho-analysis he has found this to be the case, having traced the hysterical symptoms back to some disagreeable occurrence, thoughts, or feelings in the sexual sphere.

But this is not all. The simple though sweeping statement that sexual memories are the cause of hysteria has been further elaborated. It is supposed that the primary fact is some disagreeable sexual occurrence in infantile life (say, between the ages of 2 and 10) before the actual awakening of sexual feeling which is caused by the advent of puberty; that the memory of this occurrence, which at the time is not understood, lies buried, till it is revivified at the time of puberty. Then some second event happens which brings the patient into conscious relation with sexual ideas, and the old memory is aroused, bringing with it this time feelings of repulsion and mental distress, which latter are got rid of by conversion into hysterical symptoms.

What are the primary sexual occurrences in infantile life which give rise to all this later trouble? In one of his writings, on the basis of thirteen cases, Freud declared that they were actual sexual assaults on the infant. This very surprising assertion he has since withdrawn. What he has substituted for it is, to my mind, by no means so clear or definite. He still maintains that hysteria is the remote consequence of sexual phenomena during early life. These sexual phenomena do not, however, consist in accidental or external shocks, such as assaults or occurrences of a less degree of unpleasantness, but rather in the multifarious unconscious workings within the organism which are caused by the gradual developing of the sexual organs and instincts. These in themselves are not necessarily abnormal, but as time goes on, and especially as the revelations, which accompany puberty, arrive, the memories of these workings may have to be repressed: some of them, —as, for example, homosexual impulses—for the sake of the necessary ordering of the sexual life; others perhaps because they are disagreeable to the personal consciousness of the particular individual. But how can unconscious memories be disagreeable to the personal consciousness? Either, I suppose, in the way which has been already indicated—namely, that the mental disturbance set up by the subconscious idea is felt, though the idea itself is not realized; or else—and this appears to be a new addition to the theory—by supposing that the unconscious sexual memories have become transmuted into what Freud calls hysterical fancies, daydreams, which do duty for, and are the representatives or descendants of, the original sexual memories. The struggle to repress these gives rise to hysteria, and the conversion of them into bodily phenomena gives rise to hysterical symptoms. I had better quote the author's own words:—

"The most complicated symptoms become revealed as the converted representatives of fancies having a sexual situation as a content."

And again:—

"He who can interpret the language of hysteria can understand that the neurosis only deals with the repressed sexuality."

I confess that I see little proof of these statements: they appear to me theory *in excelsis*.

Now I feel that I may be asked, "What do you think about all this that you have been telling us?" It may be said to me, "You are in the chair: give us a criticism *ex cathedra*." Well that, gentlemen, I should be very sorry to attempt. For I cannot put myself quite in the position of the authors of these theories. I have not lived among hysterical patients, as Janet appears to have done at the Salpêtrière, nor conducted, as he has done, the subtle analysis of their minds under hypnosis. Nor can I profess to be an adept in the method of "psycho-analysis" as practised by Freud. So that any criticism I may make must be of a commonplace rather than of an esoteric kind.

To my mind a purely mental theory of hysteria is not altogether satisfactory. The physical phenomena of disease seem to require physical antecedents. If it be said that there is no more difficulty in referring the symptoms of hysteria to mental action than there is in so referring the common voluntary actions of our daily life, I must reply that with some exceptional symptoms of the disease there really is such a difficulty. I mean those symptoms which are usually classed as "trophic" or "vasomotor," such as muscular wasting, œdema, hæmorrhage, and perhaps some others. Either we must deny the existence of such symptoms, as Babinski does; or we must suppose that "mind" has much more influence over "body" than most of us would admit; or we must take refuge in our ignorance of the relations between mind and matter, and suppose that hysteria occupies a ground where these two empires meet.

Still, in spite of all this, I quite admit the force of what Janet says—namely, that, considering our utter ignorance of the nervous actions which underlie mental phenomena, it may be best to speak of hysteria in terms of mind, and investigate it from the side of laws of mind about which we do know something; remembering and hoping that some day the physical revelation may come as well. Perhaps, then, a mental theory of hysteria promises best for the present. I have already indicated that this kind of theory did not get far until it adopted among its postulates the subconscious workings of the mind. About the existence of these there can be little doubt; but in such a realm both individual facts and general laws are very difficult to ascertain with certainty. They may be the best material we can get for a theory: but they are very unsubstantial, and literally "such stuff as dreams are made of."

What shall we say of Janet's view, that the psychological "stigma" of hysteria, the essence of the disease, is a restriction of the field of personal consciousness? This explains in a very admirable manner some well-known features of the disease—*e.g.*, contraction of the visual field of vision, anæsthesia, and amnesia. To extend it to sundry other features requires, I think, all this distinguished author's ingenuity. One would have thought, too, that there would be some independent evidence of the existence of such a disability; that some of the patients, at any rate, would have recognized it for themselves; and one might urge (as do Breuer and Freud) that many hysterical patients seem to suffer from no mental disability at all.

The theories of Breuer and Freud start, at any rate, with a well-established fact of human nature—namely, the relief that is experienced by giving vent to pent-up mental distress. Yet I suspect they rate the power of the confessional too high. Can we suppose that every severe and ingrained hysterical symptom would be cured in this way? About the so-called process of "conversion," which is really one of the keystones of their theory, one would like some independent proof. Is there really evidence to show that hysterical patients possess a peculiar faculty, whereby they can substitute a bodily symptom for mental distress? There is the same lack of evidence for the statement that hysteria originates in forcible repression of a distressing idea; and still more to the statement that the ideas at the bottom of hysteria are always of a sexual nature. We may grant that sexual ideas form a most important part of our subconscious mental state, and that the mental and physical manifestations of them are bound up together in the most remarkable way; but that does not prove that they are the basis, as Freud asserts, of *all* hysteria, indeed of *all* neuroses. The very example with which his theory started—namely, traumatic hysteria—proves the contrary. I know the answer made—viz., that the proof of these statements lies in the so-called facts of psycho-analysis. But can we implicitly rely on the dreamy imaginings of a patient undergoing that process? Is it not very probable that we may put into his mind just what we want to find there? We know that Freud gave up that portion of his theory which relates to sexual assaults, because he found that his patients had misled him. And if the master of this method may be deceived, how much more his disciples? To this I cannot help adding that psycho-analysis, if it is to mean the resurrection of buried sexual ideas, might to many patients do much more harm than good. The proof of the pudding, we are reminded, lies in the eating; but the dish is a little unsavoury, and I cannot help hoping that the taste for it will not become general.

These are the bare outlines of criticisms which I think might be elaborated so as to obtain some force. But I feel, gentlemen, that I have tried your patience long enough. I shall return therefore to that with which I started; and once more thank you for the honour you have done me, and this time also for the kind attention with which you have heard me.

CENTRAL NERVOUS RESPONSE TO PERIPHERAL NERVOUS DISTORTION.

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PART II.[1]

WHEN we consider that the spinal cord possesses no associative memory, and that true reflexes display a fatality in the individual and also a uniformity amongst members of the same species, we are led to assume that a complex of centripetal impulses, constituting a reflexigenous afferent unit, pursues a path through the cord which is inborn and relatively stable. The spinal animal is an automaton, whose responses to environmental change are predestined and, within limits, predictable. When, however, the motor response of an animal is directed or modified by its past individual experience we postulate that here impulses traverse cortical paths, whose synaptic mechanisms are so sensitive that their resistances are appreciably lessened by the passage of even a single impulse or impulse-group. In the cord and brain-stem the grooving is deep and the synaptic material highly tempered, so that it has been doubted whether impulses passing here along routes other than those which are reflex and inborn can, in the lifetime of an animal, so lower resistances that the new paths are comparable with the inherited. The aim of the present research was to put this latter problem to the test of experiment. The procedure was as follows: The two popliteal nerves on one side were cut and sutured so that the central internal popliteal was attached to the distal external popliteal and *vice versa.* When regeneration occurred the movements of the affected limb displayed much inco-ordination. It was obvious to the eye of the observer that, for instance, flexion of the ankle occurred when extension would have been serviceable. Slowly the animal learned to effect co-ordinated movement, though in the early stages of this education the limb was moved in so "deliberate" a manner as to suggest conscious effort and analysis. In the later stages of the educative process the movements of the affected limb were as rapid and co-ordinated as those of the sound limb in walking, running, galloping and jumping, but it was noticed that when the animal was held up by its fore-limbs, and compelled to execute progressive stepping movements with the hind-limbs, lack of co-ordination often made itself apparent in them.

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[1] Part I. appeared in this Journal, vol. xxxiii, p. 261.

When something like a year had elapsed from the date of crossing, the spinal cord was transected in the dorsal region. When the condition of shock had sufficiently abated the reflexes were tested. It will be obvious that if the cord were incapable of physical readjustment to the peripheral distortion—if it possessed no memory (in the physical sense)—severance of its connexion with the higher neural centres would lead to a reappearance of inco-ordination in the reflex acts which this cord remnant could carry out. Conversely, if co-ordination were good, then we must assume that the cord mechanisms are more plastic and adaptable than has hitherto been recognized.

In examining the limb movements great care had to be taken to avoid confusion between movements of a joint produced by muscles playing over that joint, and movements associated mechanically with flexion or extension of a neighbouring joint. Fortunately the unaffected hind-limb was always present as a control, and, moreover, some of the reflex acts we obtained could not possibly be regarded as mechanical and passive.

Experimental.

The experiments were carried out on young dogs which were anæsthetized with chloroform-ether mixture when any operative procedure was attempted.

Experiment I.—The primary operation was carried out on a puppy on May 21, 1908. The popliteals were crossed on the left side. On September 7 of the same year the animal was anæsthetized and the sutured nerves exposed, revealing a mass of fibrous tissue and adhesions. The nerves were carefully cleaned and separated by a flap of biceps muscle. The skin wound was sutured and healed normally. In this dog the progress of co-ordination was good. At first, when regeneration had just occurred, the movements of the left hind-limb were clumsy, and the left foot displayed a definite tendency to double over on the dorsum. The condition improved and, at the time when the spinal cord was transected, movements on the affected side were carried out rapidly, accurately, and apparently without attention, and were indistinguishable from those on the unoperated side. The left hind-limb was also used in scratching in a normal manner. The only evidence of incomplete co-ordination which we could find was displayed when the fore-limbs were held up, and the animal made to walk on its hind-legs. Here the left paw doubled over occasionally, but the false movement was always quickly righted.

On May 5, 1909 (a year all but sixteen days from the date of primary operation), the spinal cord was transected under anæsthesia in the mid-dorsal region. Recovery from the operation and from shock was good. When reflexes appeared they were carefully tested. *It was found that the reflex movements of the left (operated) limb were exactly the same as those of the unoperated.* The left foot participated in flexion or crossed extension arising from nociceptive stimuli in a manner indistinguishable from the foot movements on the right side. When the animal was held up by the fore-limbs, and the hind paws allowed to touch an inclined board, both hind-limbs went into extension in exactly the same way, supporting the hind-quarters of the animal, and this extension underwent the sudden inhibition characteristic of this reflex. Faradic stimulation of the glans penis gave symmetrical movements of both hind-legs and strong extension of toes on both sides. When the hind-limbs were allowed to hang motionless it was noticed that the left foot was slightly more extended than the right, but this was the only difference we were able to detect. Nineteen days after the transection a hypodermic injection of $\frac{1}{16}$ gr. strychnine was administered. As the drug took effect the glans penis reflex was obtained as described, and, when convulsions came on, the spasms in both hind-legs were exactly similar and included forcible extension of feet and toes. The animal died from the effects of the strychnine, but a quick dissection was made and stimulation applied to each popliteal nerve above and below the nerve-junction. The results showed that the crossing was nearly perfect; a few fibres had managed to regenerate connecting the external popliteal with the external, and the internal with the internal, but their action was so trifling as to be considered negligible.

Experiment II.—The primary operation was carried out on a puppy on May 21, 1908. The popliteals were crossed on the left side. On June 17, 1909 (one year and twenty-seven days afterwards), the spinal cord was divided in the upper dorsal region. Unfortunately the animal died four days after the spinal operation and we had therefore no opportunity to test the reflexes exhaustively. Some response to nociceptive stimuli was obtained and it was noticed that the movements were identical on both sides.

Experiment III.—The primary operation was carried out on a young fox-terrier on May 29, 1908. About four months later the area of operation was exposed under anæsthesia and a fairly extensive common fusion of nerves found. The nerves were separated and cleaned and kept apart by a flap of biceps. In this animal good co-ordination was never acquired; the affected foot went over on the dorsum and was often carried flexed and unused. On June 17, 1909 (one year and nineteen days after primary operation), the cord was divided in the upper dorsal region. Eight days later good reflex movements could be obtained, but it was obvious that they were not similar on the two sides. The animal was accordingly anæsthetized and the nerves exposed. Stimulation of the exteral popliteal above the nerve-junction gave rise to flexion of toes and extension of foot; stimulation of the internal popliteal above the junction gave rise to flexion of foot but no extension of toes. For some reason (scar tissue?) no regenerative union had occurred with the fibres going to the toe extensors. This experiment failed, therefore, to give direct evidence on the problem investigated; but it was not wholly useless, for the marked divergence in the reflex responses of the two limbs, owing to this flaw in the regeneration, made us more confident of our observations in the other instances.

Experiment IV.—The primary operation was carried out on an Irish terrier, about four months old, on July 9, 1909. In this case Cargile membrane was wrapped round each junction and, in addition, the two points of suture were kept apart by muscle. In this dog the improvement in co-ordination was rapid. In about eleven months no difference could be detected in the two limbs; it was also observed that the left leg was used for scratching in the normal manner. When the fore-limbs were held up the dog could walk on its hind-legs without going over on the left dorsum. On June 13, 1910, the spinal cord was divided at the level of the first lumbar vertebra. Next day the condition of the animal was poor and signs of spinal irritation were observed. When the hind-limbs were allowed to hang it was noticed that the toes on the left side were a little more flexed than those on the right—otherwise there was no difference. Two reflexes were elicited which were of value. Gently stroking the hair over the tendo Achillis produced a marked extension of the toes. This was obtained on the left side in exactly the same way as on the right. Pinching the leg above the foot gave a sort of extensor thrust involving the foot and identical on both sides. As the animal was obviously about to die it was anæsthetized and the correctness of the nerve unions verified. The animal was then killed.

CONCLUSION.

The conclusion to be drawn from our experiments is that the spinal cord is capable of an educative process if sufficient time be allowed for the new paths to traverse and outbid the old. The physical basis of habit may extend, therefore, to the deepest level of the nervous system. It is also clear that whilst the "grooving," which directs reflexiferous impulses, is certainly inborn, it is intensified during the life of the animal; but, at least in the young animal, this directive grooving is never so deep as to be "stereotyped" and incapable of giving place to new channels. Our experiments have dealt only with fundamental reflexes and those in constant operation throughout the wakeful life of the animal. They cannot be taken to prove that a dog without a cerebrum would ever associate, say, the retinal picture of its food receptacle with the act of eating. The cord, in fact, possesses only the rudiments of that associative machinery which is evolved to such an amazing degree of perfection in the cortex. Between these two extremes it is possible that all gradations may be existent.

The site of the educative change is scarcely yet within reach of experimental investigation. In Kennedy's experiments and in those in our first paper it was demonstrated that no change occurred between cortical motor cells and spinal motor cells. The educative process in these polysynaptic arcs passing through the cortex must have taken place between the pyramidal cells and the brain centripetals. The light that this fact sheds on our problem is feeble and uncertain, but it prompts the speculation that the spinal change we have demonstrated takes place in the arcs nearer to the entrance than to the exit from the grey matter.

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SOME MODERN FRENCH CONCEPTIONS OF HYSTERIA.

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IN the early years of last century a small and unpretentious volume was published (long since out of print), by George Tate, Surgeon, entitled "A Treatise on Hysterical Affections," which opens in the following engaging manner: "It fell to my lot at the age of 22 to have almost the sole charge of an extensive country practice: and although I came down from the Hospitals, as I fondly believed, brimful of information, prepared to compass every case that might present itself, I soon discovered that neither books, nor Lectures, nor Hospitals, had made me quite the practical man I had vainly imagined.

"True, I did not fall into the error of mistaking muscular pain in the side for pleurisy, nor every disturbance of the heart's action for organic disease; but some extraordinary cases of an hysterical nature stupefied and confounded me, at the same time very seriously deranging my self-complacency. . . . I sought in consultations with older men a relief from my own bewildering doubts and cares; but in vain. They could throw little light upon the deep obscure. Hysteria may well be called—

> 'An Ignis Fatuus that bewitches,
> And leads men into pools and ditches.'

For the old gentlemen fell into as many quagmires as myself. Baffled and dissatisfied, I was compelled to think for myself, and determined, if possible, to discover some general distinctive marks that would stamp the character of hysterical disorders, and enable us to base the treatment on more rational and certain principles.

"The following pages disclose the results of my studies. . . . Hysteria, in all its varieties . . . . has one common cause which is essential to its appearance: namely, an irregular or defective menstruation. Since I have been attentive to cases of Hysteric disorder, I have never seen one (with certain unimportant exceptions) either of a simple or of a complex character, in which this state of things did not co-exist."

The quaint old-world flavour that pervades the pages of this little volume is very refreshing, but the quotation has been made with another object. Hysteria is coeval with the human mind, and ever since there have been physicians at all, what has characterized the labour of many if not just this same determination to discover the distinctive marks of hysterical disorders and thereby to lay the foundation of a rational therapeusis? That the search is being prosecuted with undiminished ardour to-day can only mean that hitherto it has not been crowned with success. George Tate discovered the key, as he thought, to the problem of hysteria in an irregular or defective menstruation, and his views may not unfairly be taken as representative of pre-Charcot opinion, although both Brodie in England and Briquet in France were aware of their insufficiency and looked elsewhere for a solution of the mystery. If we pass to the epoch associated with the name of the beloved "Maître" of our French colleagues we find hysteria conclusively demonstrated to be no doubtful privilege of the female sex; its occurrence in men became an accepted fact: it was "la grande névrose," "une maladie psychique par excellence," "la grande simullatrice" of all sorts of organic disease. With the passing of the years the professional *hystériques* of the Salpêtrière, so assiduously cultivated by Charcot, have gone, or almost gone—although, as Dubois reminds us, some, like old circus horses, can still be found doing their turn—but no one who has known the wards of that famous Hospice as they used to be will deny the reality of the phenomena that once drew the whole medical world to Paris.

Charcot's views were expressed with authority, and enunciated with dogmatism, but they have not been stamped with the seal of finality. The last twenty years have witnessed renewed efforts to solve the enigma. Developing the psychical side of the disease on the lines laid down by Charcot, Janet, of the Collège de France, a psychologist of whom France may well be proud, has, in many volumes and communications, propounded and defended a frankly psychological theory of hysteria, according to which the affection "is a form of mental depression characterized by the retraction of the field of personal consciousness, and a tendency to the dissociation and emancipation of the systems of ideas and functions that constitute personality." On the other hand, Babinski, the brilliant clinician of La Pitié, amplifying in his turn a dictum of Charcot's that to be hypnotizable is to be hysterical, and that exaltation of suggestibility is common to hypnosis and hysteria, has elaborated a definition of the latter condition in the following words: "Hysteria is a special mental state capable of giving rise to certain symptoms that have features of their own. It manifests itself by primary and by secondary disturbances, the former being characterized by this, that it is possible to reproduce them by suggestion, with rigorous exactness, in certain subjects, and to make them disappear under the sole influence of persuasion."

Meanwhile, in Austria, Sigmund Freud, of Vienna, has during the last fifteen years promulgated still another psychical hypothesis of hysteria, and has modified and substantiated it in successive publications. Freud has probed the depths of his patients' minds always to discover ample corroboration of his contention—which, with all the changes he has otherwise made has never been abandoned—that "in a normal *vita sexualis* no neurosis is possible." "He who can interpret the language of hysteria can understand that the neurosis deals only with repressed sexuality." A thousand years have flown by, as Aschaffenberg reminds us, since the uterine hypothesis of hysteria led captive men's imagination, and in the sexual sphere once more is the search for light being prosecuted, but, no doubt, with a saner enthusiasm.

On the physiological side, however, endeavours have been made to devise a pathogenic theory at once comprehensive and satisfying. Sollier, of Paris, has defined hysteria as a disease associated with "a condition of cerebral torpor, or cerebral inhibition, a specialized sort of sleep analogous to what has been called vigilambulism." In England, McDougall has, in a recent article, sketched a suggestive and purely physiological theory of hysteria. There are other modern views on hysteria associated with the names of Raymond, Binswanger, Oppenheim, Mills, Hellpach, and Vogt. Finally, Dubois, of the University of Berne, states categorically that "it is useless to make an effort to give hysteria the character of a morbid entity," and this negative attitude is also that of Steyerthal.

The mere enumeration of these conflicting hypotheses may overwhelm the reader with a deep sense of despair at their hopeless dissimilarity, and he may reasonably fear that finality is as far-off as ever. But let him not be unduly distressed. Odd as it may appear, many of these contradictory opinions have one feature in common. Not only are the respective originators alike in the earnestness of their advocacy of them, but there is a curious similarity in their appeal to their own clinical experience subsequent to the adoption or enunciation of their own particular theory, and in their resort for substantiation of its virtues to the results of treatment. Thus George Tate says: "Since I have been attentive to cases of Hysteric disorder I have never seen one . . . . in which this state of things "—an irregular or defective menstruation—" did not co-exist." Further, "since the first publication of this little work an experience of many years has afforded the opportunity of testing upon a large scale the somewhat original views I have maintained upon this subject . . . . I can add nothing that would materially affect the principles or alter the practice propounded many years since. In my own hands the results of that practice have been signally successful: and so many acknowledgments bearing similar testimony have reached me from various quarters that . . . . I hope to be acquitted of an overweening confidence." Or Freud: "In all cases that I have analysed it was the sexual life that has furnished a painful affect. . . . It is not theoretically excluded that this affect could not occasionally originate in other spheres, but I must say that thus far I have found no other origin." And again, "I do not claim that I have actually removed all the hysterical symptoms which I have undertaken to influence by the cathartic method, but I believe that the obstacles were due to the personal circumstances of the cases, and not to the general principles." Or Babinski: "My conception can thus lay claim to a nosological principle that has undergone the test of time, for it is in conformity with the ancient adage: *Naturam morborum curationes ostendunt.*" And again, "In the great majority of cases I have been asked to treat I have obtained a rapid cure. Sometimes, however, ... I have been obliged to exhibit a great deal of perseverance in treatment. I also admit one or two failures, but perhaps these were cases of ordinary simulation." Or Sollier: "I may rely on the same adage as M. Babinski to demonstrate the truth of my physiological theory of hysteria, for it is based on the adoption of a pathogenic therapeusis . . . . I mistrust the validity of the principle, however. . . ." And again, "I have treated more than 200 cases, which have served only to confirm my belief in my theory, a theory which the results of treatment have shown, as by an actual laboratory experiment, to be true. All the physicians in France and abroad who have taken the trouble to verify my experiments and my methods have obtained identical results." Or, finally, not to weary the reader, Dubois, who declines to separate hysteria from neurasthenia: "If I dare to face the criticism of my colleagues, it is first because I feel that I am upheld by the friends who have become interested in my ideas; but, above all, it is because in the practice of my treatment by psychotherapy I have had such good and lasting results, that I should like to put into the hands of young physicians the instrument which I have found so useful."

To the individual who is not so absorbed in science as to lose his sense of humour it may seem that Hysteria, the while she responds so nobly to the appeals of the advocates of these various theories, is quietly smiling in her sleeve. As of old the ascetic and the epicurean, the celibate and the polygamist, the socialist and the monarch by divine right turned alike to the pages of Holy Writ for support of their particular ways of living and views on life, and found it therein, so the exponents of the sexual theory, the suggestion theory, the sleep theory, and the "hysteria-only-a-symptom" theory, alike appeal to experience for confirmation of their opinion, *and find it.* It seems to me that not only does the mere juxtaposition of the above selected passages furnish a self-evident proof of the fallaciousness of this appeal to the results of treatment, as Sollier himself has clearly recognized; it also affords a significant illustration of what appears to be as unfortunate a tendency in the study of modern hysteria as in the study of the ancient, viz., the introduction, consciously or unconsciously, of the subjective element, as I suppose for want of a better term it must be designated, on the part of the physician. More than one speaker at the recent Discussions on hysteria held by the Neurological and Psychiatrical Societies of Paris made allusion to this fact, but it has not been emphasized at all adequately. It is not merely that his hypothesis is apt to colour the physician's way of looking at a case, but also that in some obscure and little understood manner the patients come in a sense to respond to his hypothesis, so that the wider his experience the greater is the apparent confirmation of its truth. How else can we explain the facts so familiar to the student of the history of the disease? The clinics of Paris and Vienna have shown us how hysteria can be cultivated; the hysterical patients of the Salpêtrière differ from their fellows of the Pitié. In a hundred consecutive cases Babinski has failed to discover a single instance of hemianæsthesia: "as for constriction of the visual fields, dyschromatopsia, ovarian tenderness, and so on, the *hystériques* in my wards simply do not have them." "*Heureuses hystériques!*" says Sollier in an aside.

There is, I think, a profound truth in the remark of the late Professor Raymond, that the patients do not change so much as is thought; it is rather that the observer changes his point of view. Any one who reads the contributions of Freud will be struck by the way in which, in his earlier communications, he describes his open-mindedness in approaching the problems of hysteria, and how the juvenile sexual trauma eventually forced itself on his consideration till he became convinced of its essentialness. Wherever he looks now, it meets his gaze. We may say, if we will, that there are differing hysterical "types," but the interesting thing is that these types appear wherever the disease is cultivated, and that in a matter of this kind the subjective element must enter largely. Nor can the influence of environment, circumstances, and that indefinable something which is usually called the "atmosphere" of a place be ignored. Let the reader turn to the fascinating essay on "The Wandering Jew" from the pen of Henry Meige, which appeared long ago in the *Nouvelle Iconographie de la Salpêtrière*, to appreciate what the reputation of Charcot and the atmosphere of the Salpêtrière meant to the world of hysteria.

Here in England hysteria has never been cultivated. For some reason, the English neurologist has been far more concerned with organic than with so-called functional nervous disease. Not that hysteria or any of the other psycho-neuroses is a rarity; on the contrary, a six years' experience at the National Hospital in Queen Square, has afforded me opportunities of seeing cases of functional disease in abundance. But while English neurology has made many noteworthy contributions to the study of organic nervous disease, it is scarcely any exaggeration to say that hysteria has been left to itself. Curiosity has led me to scan the indices of the last ten volumes of BRAIN with the following result: out of something like 350 original articles and reports of clinical cases there are at the most ten relating, and some of these only indirectly, to disease of the nervous system of a functional sort. If there has been no school or hospital with an avowed *penchant* for the hysterical, no "Maître" to promulgate original views or disseminate the opinions of others, then the examination of our abundant clinical material has a value of its own and becomes of scientific importance, not only because of the absence of mental prepossession on the part of the examiner, but also because of its prosecution almost entirely—I speak of the methods in vogue at the National Hospital—on objective lines. It is on the adoption of the objective point of view that our expectation of progress towards the unification of the disease must depend. From such methods of procedure facts can be gleaned which may be shown to be full of significance for an explanation of the psycho-physiological mechanism of the diverse phenomena of hysteria.

In the following pages a *résumé* of the hypotheses associated with the names of Babinski and Janet will be given, and acknowledgment made of the great merits of these theories, and of the services they have already rendered towards the elucidation of the subject. Various points on which the hypotheses are open to criticism will be referred to, in support of which sundry clinical cases will be quoted. One or two matters already briefly noted in this introduction will be more fully discussed, and a scheme whereby to approach the problem of hysteria from the objective standpoint outlined. For permission kindly granted me to refer to various cases under the care of different members of the Medical Staff of the National Hospital, every one of which has been personally observed, I wish here to express my most grateful thanks.

CHAPTER I.

Babinski's Conception of Hysteria.

For a right understanding and appreciation of the attitude now adopted by Babinski towards the problem of hysteria, it is essential to preface an account of his views with one or two brief, but none the less important, considerations. Since the title of his most important contribution to the subject is "The Dismemberment of Traditional Hysteria," we must be perfectly clear as to what he really intends thereby.

We must first disabuse our minds of the idea that where hysteria is concerned, the "Salpêtrière school" and the "French school" are interchangeable terms. In spite of the dogmatism that characterized it, Charcot's teaching was never accepted in its entirety by some of the French provincial schools, notably the small but very active one at Nancy. At the latter place, Liébault and Bernheim found themselves in direct antagonism to Charcot on the important, and, as it once appeared, fundamental question of the relations between hysteria and hypnotism. Charcot taught that the two were intimately associated, that to be hypnotizable was to be hysterical, and to be hysterical was to be hypnotizable. Time has shown the inaccuracy of these opinions, for most experts are agreed that hysterical patients are difficult to hypnotize, while so large a percentage of normal individuals are hypnotizable, that the idea of their all having latent hysteria is absurd.

Again, the comparative paucity, at least in the Charcot days, of the contributions to the study of the neurosis emanating from observers in Germany, England and America, may not unfairly be taken, in one sense, to be an expression of an undercurrent of feeling that "traditional hysteria" was peculiar to Paris, and that it was necessary to go to Paris to observe it. Hints of this sort were openly expressed by some

German clinicians. It is not so to-day, of course, for once the didactic descriptions of Charcot permeated the text-books of these countries the disease was more readily diagnosed and, as is always the case, instances of it seemed to multiply. In spite of the fact, however, that full-blown hysteria can be found in Berlin or London, or, for that matter, in any country village, in as complete a form as in Paris, there has been a vague or tacit disinclination on the part of other medical schools to subscribe wholeheartedly to the dicta of the great French observer. Just as clinical experience has long ago furnished proof of the relative rarity, in this country at least, of the "classical" type of disseminated sclerosis, according to Charcot's masterly exposition, as compared with "formes frustes," so there has been a feeling that the "classical" hysterical patient is a *rara avis*, and that many of the bizarre symptoms complacently attributed at the Salpêtrière to the great neurosis were thus classified through ignorance of their real significance. When, therefore, Babinski attacks the citadel of "traditional hysteria," we must remember that some never considered it to be in a strongly entrenched position, while it has long shown signs both of the assaults of critics and of the ravages of time.

On the other hand, it must not be forgotten that Charcot himself was fully convinced of the psychical nature of the affection, and when he determined the important *rôle* played by the "idée fixe" in the genesis of its symptoms it must not be overlooked that he was formulating a psychological hypothesis which his successors have merely amplified and elaborated. It was his to have demonstrated, by scientific methods, the possibility of reproducing hysterical symptoms experimentally by suggestion and of effecting their disappearance in similar fashion. Now let it be said at once that in Babinski's opinion hysteria is a disease of the psychical level, and that the relation of suggestion to its phenomena is cardinal. In what sense, then, have his criticisms resulted in a dismemberment of traditional hysteria?

In a famous lecture on hypnotism and hysteria delivered at the Salpêtrière on June 23, 1891, Babinski said: "*mon intention . . . . est de vous rappeler cette vérité, dont il est indispensable d'être bien pénétré, que le domaine de l'hystérie est infiniment plus vaste qu'on ne croyait autrefois.*" In his brochure of 1909, he says: "*tous les médecins reconnaissent actuellement que le domaine de l'hystérie traditionelle a été démésurément étendu.*" To read these two statements consecutively is to appreciate at once the change in Babinski's point of view, and the latter of them may be taken to constitute his first criticism.

(1) *The term "Hysteria" has become too Comprehensive.*

In the world of medical thought there always have been sundry conceptions, unstandardized and variable, sometimes defaced and depreciated, which nevertheless pass as current coin. By their aid we often win credit where none is due, for classification and diagnosis are not synonymous. Half a dozen such readily suggest themselves. "Neurasthenia," "neuritis," "hysteria," are veritable godsends to the incompetent or the indolent. Of any of them might be said what Lasègue said of the last: "It is a basket for papers we don't know where to place." Gowers has varied the metaphor by declaring that "hysteria is a conception that conceals whatever it covers; we must rescue from it whatever we wish to study." Everyday observation teaches us that vagueness in our connotation of a nosological term has for sequel the unjustifiable multiplication of apparent instances of the disease. And conversely, if we seem to find cases of a given disease wherever we turn we may well question whether our conception of it is sufficiently precise. These remarks may be applied pertinently to the subject of discussion. To the student more particularly of the French literature of hysteria there will recur, as he turns over the pages of his "Charcot," not only the wonderful attacks in all their stages, the stigmata, the somnabulisms, the "fugues," the multitudinous motor and sensory phenomena, the paralyses, contractures and tremors, the anæsthesias and hyperæsthesias, but also the hæmorrhages, hæmatemeses, hæmoptyses, erythemas, the ulcerations and even gangrenes, the inflammations, œdemas, anurias, polyurias, hæmaturias, and albuminurias—in short, the whole gamut of symptomatology, until he puts away the volumes to seek relief in the comforting generalization, that "l'hystérie peut tout faire."

We must beware, however, of assigning all responsibility for the production of this conglomerate to Charcot himself; his successors extended the hysterical horizon immoderately, till the conception of hysteria was bounded only by the limits of the mind itself. It is sufficient in this connection to remember that Möbius, one of Charcot's followers, considered *all* morbid phenomena hysterical that were produced by ideas, but the broader such a conception is, the shallower it becomes.

No one, then, will quarrel with Babinski when he proceeds to examine the causes of this unwarrantable extension of hysteria, and finds it has been determined by erroneous diagnosis, by undetected fraud or simulation, and by the inclusion of symptoms common to other morbid conditions, or by the confounding of certain nervous states that ought to be distinguished. Of course, these are exactly the causes of the unjustifiable extension of the limits of *any* nosological entity; there is nothing specific about them. They apply equally well to neurasthenia. That the domain of hysteria, however, has come to range from insanity to renal disease, and from doubled personality to gangrene, is ample evidence of the necessity for a complete reinvestigation and restatement of the problem, and therefore Bābinski's first contention, which he has persistently brought before the profession during the last ten years, is one that commands universal approbation.

(2) *The Codification of Hysteria has been too Artificial.*

In his cliniques Charcot encountered the difficulty with which all teachers are confronted, namely, how to combine the proven and the not proven in the presentation of a subject suitably to the requirements of the student. An authoritative personality such as his could not be content to doubt; consciously or unconsciously his views were propounded with an increasing degree of dogmatism, until the conception of hysteria, stretched to the utmost, lost its elasticity, and became fixed. In this fully organized form it may be sketched as follows.

Hysteria manifests itself by two classes of symptoms, one comprising what are known as fixed stigmata, the other transitory. Of the stigmata, which in addition to being permanent usually develop independently of the patient's knowledge, we may specify hemianæsthesia, anæsthesia of the throat, unilateral affection of the special senses, constriction of the visual field and dyschromatopsia, also "points douloureux," ovarian tenderness, &c. Among the transitory or mobile phenomena are fits, attacks, *crises*, palsies, contractures, tremors, spasms, aphonia, mutism, &c., which usually appear suddenly, under the influence of an emotion, and may disappear equally suddenly. In addition to these two classes, a long train of complications, cutaneous, vasomotor, trophic, &c., ought to be mentioned as included in the conception.

Now while cases illustrating many or most of the above-mentioned features, and constituting an hysterical museum, assuredly do not run about the streets, yet under the influence of Charcot's teaching, once a diagnosis of hysteria was made, the examiner almost invariably endeavoured to detect one or other of the stigmata, hoping thus to bring his case into line with the classical description of the disease. The discovery even of a single symptom apparently of an hysterical nature was enough for this purpose. There can be no doubt that by procedures of this sort patients were directly, if unintentionally, invited to bring symptoms and signs into being. Such was the result of the codification of hysteria.

Against this manner of thinking and way of examining Babinski has declared himself fundamentally opposed. Investigations conducted without any preconceived ideas have led him to the conclusion that the so-called stigmata are not characterized by any fixity, "except in the case of certain professional hysterical patients, for whom the disease is a means of livelihood, and who are simulators rather than patients." Further, he denies that the patient's ignorance of the presence of these stigmata constitutes a cardinal feature; they are the consequence either of auto-suggestion, or of unconscious suggestion on the part of the examining physician. If only sufficient care be exercised, hemianæsthesia, visual constriction, ovarian tenderness, &c., are conspicuous by their absence. "Les hystériques de mon service n'en ont pas." In one hundred consecutive cases of hysteria in both sexes, patients who had not undergone any previous neurological examination, he failed to find a single instance of hemianæsthesia. Tactile, painful, temperature, muscular, and stereognostic impressions were all tested. A statement like this, from a clinician of world-wide reputation, is a very remarkable one, and merits weighty consideration.

Similarly, the features supposed to be characteristic of the transient symptoms of hysteria—their relation to emotion, and suddenness of appearance and disappearance—are not peculiar to hysteria and cannot therefore serve as distinguishing marks. They cannot be utilized for purposes of definition.

We may here remark that Babinski is avowedly in search of criteria by which to define the disease, a notoriously delicate matter, especially since it is hysteria that is concerned. The determination and statement of its proper characters are no doubt all that is required, and in strict conformity with principle, but even though there should be unanimity on the subject of what pertains to hysteria and what does not, a definition depends so much on the point of view of its creator that it may not meet with general acceptance. One of the most curious things about hysteria is just this, that while there is seldom any difficulty in coming to a diagnosis between it and organic nervous disease, and while there is a wide symptomatology accepted by the whole medical world as hysterical, agreement on a definition of the affection is still very far from being achieved. The explanation lies partly in the fact that misunderstanding may arise on the nature of a definition.

The latter may be nosographic or it may be pathogenic; in other words, it may consist of an attempt either to summarize the pathognomonic symptoms of a disease, or else to bring into relief the connection between the nature of the disease and the symptoms to which it gives rise. We shall discuss later the definition of hysteria framed by Babinski, but we must remember that in his criticism of traditional hysteria his methods throughout have been constructive as well as destructive, and that his goal has been the establishment of a definition.

We have seen, then, the profound dissatisfaction with which Babinski regards the standard symptomatological descriptions of hysteria; but it must be noted clearly that he does not gainsay the reality of the symptoms themselves. He accepts the great majority of them, denying only the importance of the attributes of fixity, abruptness of appearance and disappearance, transience, independence of the patient's knowledge, &c., attached to them, and independent investigation leads him to the conclusion that they may be characterized in another way. The points on which stress has hitherto been laid in the delineation of hysterical symptoms and signs are not, in his opinion, the proper points to emphasize. His contention is, that the manifestations of hysteria have only two attributes that are cardinal, essential, and sufficient—viz., on the one hand, the property of being reproducible by suggestion, with rigorous exactitude, in certain subjects, and on the other hand, of disappearing under the exclusive influence of persuasion.

Since these attributes of the symptoms of hysteria have met with considerable adverse criticism, we must specify the sense in which the terms are employed. By "suggestion" Babinski intends to express the process by which we endeavour to make someone accept or realize an idea which is patently irrational. To tell him on a fine, dry day that it is cloudy and pouring with rain, is to "suggest," for the allegation is in flagrant disaccord with observation; to tell a patient whose muscles function normally that he is hemiplegic or paraplegic is similarly to "suggest." On the other hand, to assure a patient that the "paralysis" from which he is suffering will vanish at once, by the aid of the will, or by electrotherapy, or any other means, is to "persuade."

Babinski has amplified his selection of these attributes into a definition which, in its latest version, is couched in the following terms:—

Hysteria is a special psychical state capable of giving rise to certain disturbances with characters of their own.

It manifests itself principally by primary symptoms, and by secondary or accessory symptoms.

The former can be reproduced by suggestion with rigorous exactness in certain subjects, and can be made to disappear under the sole influence of persuasion.

The secondary symptoms are strictly subordinated to the primary ones.

Armed with this definition, derived from an independent study of the symptoms of hysteria, Babinski proceeds to reconsider these symptoms in the light of the knowledge thus gained, using his definition as a touchstone.

(1) Some of the symptoms characterizing "classical" hysteria can be reproduced by suggestion, others cannot. To those which can thus be reproduced, and removed by persuasion, he proposes to apply the epithet "pithiatique" (πειθώ, I persuade, ἰατος, curable), and to denominate the process "pithiatisme." As far as I am aware, Babinski nowhere supplies a detailed list of the symptoms which he has been able to reproduce successfully "in certain subjects," but a quotation will serve to indicate the more important of them:—

"The principal are convulsive attacks, paralyses, contractures, highly variable in their localization and intensity, tremors, choreic movements, sometimes irregular but usually rhythmical, troubles of phonation and respiration, disturbances of sensibility (anæsthesia or hyperæsthesia), disturbances of the special senses, bladder troubles . . . Suggestion is incapable of exaggerating or abolishing tendon reflexes, of altering the pupillary or cutaneous reflexes . . . It cannot produce vasomotor, secretory, or trophic affections, nor can it create hæmorrhages, anuria, albuminuria, or fever."

(2) There are other symptoms often associated with hysteria, and usually held to constitute as integral a part of the conception as any of the pithiatic symptoms. These are more particularly liable to arise as a sequel to an emotional shock, and are referred to by Babinski as "emotive." While he considers that, speaking generally, the *rôle* of emotion in the genesis of hysterical symptoms has been grossly exaggerated, he does not deny that it is incontestably the direct cause of the appearance of some symptoms, viz., tachycardia, vasomotor changes, erythema, disturbances of cutaneous and intestinal secretions. The essential difference between these symptoms and those of the first group is that the former are independent of volition, while the latter, in form, duration, and intensity, are determined by it.

(3) There are still other signs, usually included in the conception of hysteria, which concern reflectivity, viz., generalized exaggeration of the tendon reflexes, and impairment of the cutaneous vasomotor reflexes (dermatographia). This group is fundamentally different from the first two, inasmuch as the phenomena are independent of any psychical influence, and have nothing to do either with suggestion or emotion.

Tested, then, by the suggestion criterion, the symptoms of hysteria are seen to fall into three groups, immiscible and unassimilable. In the opinion of our author, comparative researches negative the possibility of the establishment of any intimate relation between the first group and the other two. As a consequence, it is irrational to apply the same terminological expression to all; then why, he asks, prolong the usage of the word hysteria? Convention will decide the matter, but misunderstanding can be most easily avoided by the adoption of the term "pithiatism," to indicate the autonomous group of symptoms comprised in the first of the above categories.

If the reader has followed this brief sketch of the rise and development of Babinski's present views on the subject, he will recognize that they are practically a generalization from an opinion of Charçot, as has been pointed out by various writers, and as has been already mentioned in the introduction to this paper. His statement, in the opening paragraph of his brochure, that the results of his researches have induced him to abandon the doctrines of his illustrious chief, must be understood in the light of his criticisms already referred to, that the domain of hysteria has been unwarrantably enlarged, and its codification has been too rigorous. So far from abandoning the doctrines of Charcot he has taken one of the latter's main contentions, and made its absolutism a test for all clinical data that seek admission to the syndrome. Now while Charcot was probably one of the first to demonstrate scientifically and experimentally the action of suggestion, we must remember that long before his day it was fully recognized, if little understood. If we turn to the pages of Mesmer, we shall find ourselves in a world of magnets and metallo-therapy, but it is one in which the part played by suggestion in the development of palsies and anæsthesias is richly exemplified though imperfectly appreciated. Or if we scan the instructive appendix to Paul Richer's "Hystéro-epilepsie," we shall come across innumerable instances of the same process, and of the closely allied process of imitation, at work through the ages. Not only so, we shall find hysterical symptoms disappearing, as they do to-day, under the magic influence of persuasion. What though the "persuasion" may not always have been of the gentler sort? After all, it was but an exteriorization of the thought of the time, and we could not expect the spiritual healer of the Middle Ages to have ignored the power of the temporal arm of the Church. "Les grandes victimes de l'hystérie," on the other hand, form a small army to bear witness to the occasional failure of "persuasion." At the discussion Ballet particularly emphasized the fact of the antiquity of the symptoms known as "troubles par suggestion." What Babinski has done, then, may be put in another way. He has taken indisputable hysterical symptoms and analysed them afresh from the point of view of the common features they present; and among these the only character he can find that is not only common to all, but *peculiar* to all, in the sense of distinguishing them from all other disease symptoms, is this possibility of reproducing them by suggestion, with rigorous exactness, "in certain subjects," and of making them vanish under the sole influence of persuasion.

It is no little service to have cleared the air in this fashion. With that desire for precision which is one of the distinguishing features of the Gallic mind, Babinski has set before himself the laudable aim of reorganizing an unwieldy nosological conception and of limiting the sphere of its operation. By selecting what appears to be a characteristic of most hysterical phenomena for a diagnostic and pathognomonic sign, he has occupied a strong position, which we may now proceed to examine in greater detail.

In the first place, we owe him a debt of gratitude for exposing the ease with which faulty methods of examination can originate hysterical symptoms. Mankind falls an easy prey to suggestion. There is a tale of some traveller, a wretched sailor, who, late one evening, went on board a liner on the Manchester Ship Canal, under the impression it was to sail at once. He was violently sick all night, but in the morning found to his disgust that the boat had not stirred from the quayside. In hysteria the suggested idea is paramount. The hysterical subject is incredibly sensitive to suggestion. Merely to mention a symptom is to bring it into existence, sometimes with a rapidity that is bewildering. I well remember a case of severe hysterical paraplegia in a young woman who had been seen by several physicians in consultation, one of whom came to the conclusion that the case was one of chronic myelitis, but admitted, unfortunately in the patient's hearing, that it was odd there were no bladder symptoms. The patient promptly obliged by developing incontinence of urine, which continued for six weeks! Of course, the hypersuggestibility of the hysterical patient is notorious, but the point for the examining physician to keep steadily before him is his responsibility in view of this trait in the hysterical character. To my mind, the greatest service Babinski has rendered to the study of the subject is his demonstration of the frequency with which the so-called stigmata of hysteria have turned out to be the fruit of unconscious suggestion. Reference has already been made to his series of a hundred cases of hysteria in which no trace of anæsthesia was discoverable, and to his failure to detect any constriction of the visual field, dyschromatopsia, ovarian tenderness, &c., under similar conditions. At the discussion there was remarkable unanimity as to the frequency—though not the constancy—with which hysterical anæsthesias are attributable to maladroit investigation. In such cases, as was remarked in the introduction, we have convincing evidence of the curious way in which clinical experience reacts upon nosological conceptions, which, in their turn, colour our interpretation of clinical phenomena.

In the next place, the firm stand which Babinski has taken in casting grave suspicion on the advisability of allowing such symptoms as hæmatemesis, hæmoptysis, hæmaturia, albuminuria, anuria, or such skin conditions as pemphigus, or such trophic lesions as ulcers and gangrene, to enter the category of hysteria, has had a salutary effect. As Jelliffe says, hysteria is no longer a morbid entity, it is a *cohors morborum*, and it is high time the work of critical disintegration had full play. Cases with the above-mentioned symptoms have been published that are certainly difficult of explanation except on an hysterical basis, but to dogmatize thereon is a serious mistake. Many observers, no doubt, never having had any experience of such symptoms in their cases of hysteria, have legitimately questioned the appropriateness of assigning them to the great neurosis, in the apparent absence of organic disease, and this, of course, is the attitude to be adopted, and that ought always to have been adopted. It is the case, nevertheless, that such symptoms have been ascribed to hysteria in its faculty of *tout faire*, hence the desirability of removing them outside the pale altogether—any of them may be put back again if necessary. If mistakes have occurred in assigning to hysteria nervous symptoms, which have afterwards turned out to be of organic origin, how much more likely are they to happen when the symptoms in question cannot be said to be nervous at all, in the ordinary sense?

Babinski, too, has given the weight of his clinical authority to all proposals or methods which have for their object the removal of the hysterical patient from circumstances or environment likely to influence him or her in a deleterious way. The direct outcome of his views on hysteria is a vivid appreciation of the harmfulness of imitation and contagion where highly suggestible patients are concerned. It is a commonplace that the whole modern treatment of hysteria, whatever be the theory of the physician, represents a radical change of front from the position of thirty years ago, but this change has seemed to be so natural a development that it is impossible to apportion the credit to any particular individual or school. Babinski's views on the neurosis, however, make it logically imperative for anyone who holds them to treat his hysterical patients in a fashion that is calculated to result in nothing but good. The days are gone when the physician entertained the possibility of studying symptoms and of curing them at the same time.

The views which Babinski has promulgated have met with a good deal of adverse criticism, as anyone can see for himself who reads the discussions at the Société de Neurologie of Paris, and at the joint meetings held with the Société de Psychiatrie. The official report of the joint meetings alone occupies 136 pages of the *Revue Neurologique*. Among those who have not been converted are such well-known names as Dejerine, Raymond, Ballet, Janet, Pitres, Sollier, Cestan, Dufour, &c. Others who have criticized adversely are Oppenheim, Claparède, Jelliffe, Vogt, &c.

Criticism may be directed (1) towards the definition of hysteria proposed by Babinski, and (2) towards the views on which that definition is based.

(1) As has already been pointed out, a definition may be regarded as either nosographic or pathogenic; either it is intended to express concisely the pathognomonic symptoms of a disease, in which case it must be the final outcome of a synthetic study, and not a fundamental condition of this study, or it may represent an attempt to express the hypothetical nature of a disease and the pathogenic relation in which the symptoms stand to it. Now we have seen that Babinski has evolved his definition from a consideration of certain unmistakeable hysterical symptoms, and with this definition as a criterion he proceeds to test the very symptoms from a study of which he has derived it. We are, therefore, left in doubt whether it expresses a theoretical opinion as to the

nature of hysterical disorders, or whether, in Claparède's words, it is simply an empirical enunciation of a diagnostic sign. At the opening of the discussion Babinski contended stoutly that delimitation of a subject must precede its systematic study, but several members who took part protested against this method of procedure, on the ground that his demand was legitimate only if the delimitation be accepted as a provisional approximation. Yet this is not the attitude Babinski has assumed. He makes his definition a Procrustean bed on which he lays the phenomena of the disease, which are as a result either lopped off without compunction, or stretched and strained so that they are made to fit it. In my opinion the writers who have condemned its artificiality have every justification for so doing (Claparède, Sollier, Crocq, Oppenheim, Raymond). While it may be admirably applied to the pithiatic symptoms of hysteria it leaves out other symptoms frequently found in association, though not perhaps reproducible "in certain subjects" as the former are. Forcibly to eject them, on this ground only, from the category of hysteria, is, as Raymond says, "to sin against nosology."

Sollier, further, has criticized the definition itself in a trenchant manner, and indicated the *petitio principii* which is involved. If hysterical symptoms are characterized by the facility with which they can be reproduced *chez certains sujets*—so indefinite is the definition—we may well wonder who these subjects are. Babinski says the procedure is "to observe suggestible individuals attentively and to experiment on them. Preference should be given to subjects formerly known as *grands hypnotiques*, for they possess an extraordinary degree of suggestibility. Others may be taken if they will lend themselves to investigation." We cannot avoid the uncomfortable feeling that some at least of these subjects are suggestible because they are hysterical. Thus the definition is not free from the grave ambiguity of leaving us uncertain whether it does not contain implicitly the very term which it seeks to define.

At the discussion another criticism of an entirely different nature was passed by Dufour, but it does not seem to have attracted the attention it deserves. It appears to me a very weighty objection indeed. Dufour remarked that "in accepting the definition we define a disease by the relations between the patient and the physician, thereby employing therapeutic rather than etiological terms. It is preferable to base it not on the influence which the physician exercises on the evolution of the symptoms, but on a consideration of the symptoms themselves freed of all pithiatic influence." I am fully convinced it is only by painstaking study of the objective characters of hysterical symptoms that real advance will be made, and it is one of the odd features of the hysterical controversy that Babinski who, more than any other clinician, has supplied us with precious objective signs to distinguish organic from "functional" disease, should base his definition and erect his symptomatology on an essentially subjective standard.

(2) (*a*) As a sequel to what has just been said of the definition itself, when we pass to consider the data on which the definition is based, the first point I wish to draw attention to is that *we have no standard or criterion of suggestion or persuasion.* They are measured by the personal equation, which is not a known quantity. Who is to decide whether a given symptom is hysterical in Babinski's sense or not? The criterion is subjective, not objective. Everything depends on the influence exercised by the operator, and success is not the prerogative of all. As far as persuasion is concerned Milne Bramwell, after years of special experience, expresses the following matured opinion: "Apparently the main factor for success is systematically repeated suggestion, but just what gives it its value I know not. Of analogous cases treated in this way by the same operator, some will recover and some will be uninfluenced. Again, while using identical methods, one person may succeed in a given case and another fail in an exactly similar one. Further, operators whose methods are widely different may be equally successful. *Possibly the most important thing is not so much the method as the man behind the method.*" (The italics are my own.) Let us suppose a patient to be suffering from a flaccid palsy of the right arm, with no sensory disturbance, and that the practitioner is unable to decide from the imperfect history given him whether he is dealing with an hysterical monoplegia or a case of poliomyelitis. He finds no obvious indications of hysteria in the patient. Objective signs will enable him to draw a distinction immediately and with a minimum of doubt, but Babinski's definition demands the exact reproduction of the symptom by suggestion "in a certain subject." Well, our practitioner may be unable to effect this. Can it be removed under the sole influence of persuasion? Perhaps it may, but our practitioner, in spite of every endeavour, again may be unsuccessful. Thus its hysterical nature cannot be determined. Babinski responds that even when we fail we know that the palsy is *susceptible* of being cured by persuasion. But if we fail, how do we know? How can we possibly know?

In this connection two cases have been reported by Raymond, and are specially instructive because the nature of the symptoms was such as to lead the observer to suspect he was dealing with organic disease.

One was a case where a cook suffered from œdema of the hand, with complete hemianæsthesia of the same side of the body. Surgical and medical treatment alike were entirely ineffectual, while Charcot, to whom the case was referred, made a diagnosis of hysteria. After leaving hospital the patient came unexpectedly into a small fortune, when the œdema and the hemianæsthesia suddenly disappeared! It is true that Raymond had not thought of making that special suggestion which was the means of effecting a cure. Another patient, affected in a similar way, proved rebellious to all persuasive dialectic, but his voluntary immersion in the piscina at Lourdes was followed by instantaneous disappearance of his symptoms.

The point is that, if we argue from Babinski's diagnostic standard, these symptoms could not have been hysterical, yet the sequel showed that they were. They would have been thought organic had they not vanished as by the stroke of an enchanter's wand. Babinski's answer to somewhat similar objections to his conception of hysteria is, that in all probability the patients were told they would get better suddenly, even though the physician was himself unable to effect the cure, and that this was an auto-suggestion or a subconscious persuasion on which the patient acted when the psychological moment arrived. This is simply an assumption which it is impossible either to prove or to disprove without further information, and in any case, to leave the final determination as to the hysterical nature, or otherwise, of a given symptom to the off-chance of the arrival of the psychological moment is unsatisfactory and unpractical.

Or I might illustrate further by a reference to a case of hysteria, which I have had many opportunities of observing during the last two or three years.

A young woman came into hospital suffering from an hysterical spasm of the neck musculature. When this was modified under suitable treatment hysterical aphonia developed, and remained peculiarly rebellious to therapeutic measures. Faradization resulted in the aphonia becoming a complete mutism. Then, by way of change, the patient developed a remarkable spasm of phonation, so that she spoke extraordinarily loudly, but slowly and jerkily. This phenomenon changed again to mutism, and in spite of hypnotic measures and psychotherapeutic efforts of every description, persuasion remained an utter failure. Long after she had left the hospital and was living quietly at home, mute as ever, she found one evening in a box a pencil portrait of her dead father, in regard to which she had had a discussion with her aunt as to whether the head was drawn in profile to the right or to the left. She had maintained it was drawn to one side—it is immaterial which—while the aunt had thought it was to the other side. On discovering the sketch she suddenly cried out, "I'm right!" and then said, "Oh, I've spoken, auntie!" From that moment her recovery was complete and lasting.

Cases of this type are common and familiar enough. It is cited simply because it cannot be judged either by suggestive or persuasive criteria. Persistent interrogation failed to elicit any evidence of suggestion—there certainly was no suggestion that aphonia should be succeeded by mutism!—while persuasion was an abject therapeutic failure. Yet the case was patently one of hysteria, determined and diagnosed according to its objective characters. Where Babinski fails to cure a case by persuasion, he has reason to suppose that the patient is simulating. The young woman in question, however, was a school teacher, anxious to get back to work, and, moreover, particularly happy now that she is at last able to resume it. The assertion that such a case is at least *susceptible* of cure by persuasion, even though the observer fails, is entirely beside the point. How, I repeat, are we to know this? I do not deny for a moment that anyone examining this patient might say that her symptoms could be reproduced with rigorous exactness "in certain subjects," and that, therefore, they come within the category of hysteria. Certainly, but how are we to decide that the reproduction is exact? The only possible way, surely, is by a comparison of the *objective* characters of the phenomena in the patient and in the subject experimented on. This at once takes us away from the criteria Babinski has endeavoured to establish; there being no standard of suggestion or persuasion, we cannot appeal to them for diagnostic purposes.

But further, Babinski himself tells us that he has, by suggestion, been able to reproduce the symptoms of Sydenham's chorea with such exactness that he could not distinguish the copy from the original. Now if we cannot distinguish between the objective characters of a *suggested* chorea and an *organic* (not hysterical) chorea, there can be nothing specific in the symptomatic aspect of suggestion phenomena, and therefore they cannot be said to teach us anything.

(*b*) *Babinski's tenets cannot explain adequately the frequent association of certain symptoms with pithiatic symptoms, nor the frequent occurrence in hysteria of phenomena originating apparently in simulation.*

According to Babinski the realm of hysteria has been enlarged unwarrantably by the inclusion to an extraordinary extent of fraudulent cases. Everyone admits that conscious fraud would flourish were it not for the watchfulness of the physician; but, putting aside flagrant and gross malingering, we meet with apparently conscious simulation of a more subtle kind. Thus I have seen a patient with a complete hysterical hemianæsthesia stand beside her bed looking out of the ward window, and at the same time fumbling in the drawer of her locker with her anæsthetic hand to find a hairbrush, which she did quite easily. I have noticed a patient with profound paraplegia of the typical hysterical sort move her immobile legs while she lay half asleep. I have observed another patient, whose hysterical right arm hung helpless by her side, move it briskly to her face to avoid coughing in front of the physician. In each instance the patient offered no explanation of the incident, but simply repeated her tale of inability to move the limb, or of complete loss of feeling. These facts are of great interest, and their explanation is difficult. According to Babinski, there is no objective difference between a suggested paraplegia and a simulated paraplegia; the only means of differentiating them is by a consideration of the state of mind corresponding. The simulator is conscious of his actions, while the suggestible individual is unconscious of them, or rather subconscious; " he is a sort of half-simulator." Whether this not very clear distinction can be maintained, even assuming that it can be detected, is highly problematical; in spite of the apparently volitional nature of the incidents above referred to by way of illustration, I do not think that the patient is fully conscious of his actions, and I certainly should not like to stigmatize him as an open fraud. It appears to me that the movements are volitional only in appearance, and that the conscious ego does not participate therein, so that no real distinction can be drawn between the two groups. It is therefore a serious defect in Babinski's views if he is unable by an appeal to their guidance to differentiate between what is suggested and what simulated. And it is surely a very weak position to adopt to say, that "the failure of psychotherapy, practised under good conditions and with perseverance, ought to incline to the belief that the case is one of simulation"; in other words, if we cannot cure a patient, then we must question his sincerity.

There are other phenomena of a simulated kind, which Babinski is unable to evolve by suggestion—viz., anuria and fever. And there are still others characteristic of so-called hysteria mutilans, in which erythemas, ecchymoses, ulcers, and various sorts of eruptions appear spontaneously, according to the protestations of the patient, but in reality as a result of some jugglery or artifice. Is it a mere coincidence that so many of these cases have shown symptoms of hysteria? Are they suffering from a psychopathic condition distinct and separable from that neurosis, or is there some link between the hysterical mind and this mythomaniac tendency? Our author, of course, would exclude them absolutely, not only because they cannot be suggested, but because, not having any proper label attached to them, they have probably been thrown into the hysteria basket. Since their occurrence in combination with frankly hysterical symptoms is so frequent, for nosological reasons we ought to hesitate before summarily rejecting them. Take the following case:—

A young girl, aged 15, with a marked neuropathic family history, had a sister who hurt her foot so that it turned inwards. The patient unconsciously copied this, and when her attention was drawn to what she was doing, the contracture became worse; the toes were contracted and immovable, but found to be quite pliable during sleep. At the same time, wishing "to be coddled," "to be laid up for a little while," like her sister, she drove a large carpet tack into her right foot, but cannot remember whether it was painful or not. The foot became septic, and all sorts of complications ensued, but complete recovery eventually followed.

When aged 19, in order to make the mistress of her school, of whom she was passionately fond, love her more, she cut the back of her left hand with glass. It was not particularly painful. "I cut my glove, too, and pretended that I had been run into by a man carrying a frame of glass."

The next year, her mother being ill and in bed, the patient wanted to lie down, too, and "be made a fuss of." She therefore conceived the idea "it would be nice to have spinal disease." After waiting some weeks she procured some nitric acid, dipped a spun glass brush into it, and rubbed it up and down her back one evening. The back at once blistered and was exceedingly painful, but she had a quantity of white lead ready, and this she rubbed into her back as well as she could. When she could bear the pain no longer she gave in, and was put under treatment at once, at the same time developing typical hysterical *crises.*

A few years later, under circumstances which need not delay us here, she developed a highly characteristic, severe hysterical paraplegia, with complete analgesia to the waist and over the whole of the rest of the left side. When she was in hospital I frequently detected her pushing pins into her left arm, and on more than one occasion I found fragments of needles broken off and left under the skin on that side. This patient was observed several times to move her legs in sleep, although during her waking hours they were immobile, blue, and cold. The reflexes were normal, except that the plantar reflex was absent on both sides; there were no contractures, no wasting, no bladder affection, no bedsores, no change in electrical excitability of the muscles.

Dr. Ormerod has published the record of a peculiarly instructive case of hysterical hemiplegia in a patient under his care when I was his house physician, in whom a skin eruption of so remarkable a nature as to make its artificial origin practically certain, developed on the affected side. The patient protested strongly that it came spontaneously and offered no explanation of it.

Cases like these present problems that cannot be settled by the simple device of calling the deception symptoms mythomania and raising it to the dignity of a syndrome. To my mind a strong case can be made out for the view that in many instances this need for deception or simulation (in the first case quoted it is coupled with a remarkable degree of imitation, the twin sister of suggestion) may be an expression of the hysterical mind and temperament, and its admitted association with classical hysteria ought to lead to hesitation in rejecting it. The fact that Babinski can find no characteristic signs to distinguish the hysterical from the simulated matters little, however unsatisfactory from his special point of view, for it is the state of mind preceding the development of the respective symptoms that requires meticulous analysis. The bare division into conscious and subconscious simulation is inadequate.

The same objections may be advanced in regard to another group of symptoms which many competent observers (Raymond, Pitres, Vogt, Oppenheim, &c.), in spite of Babinski's opposition, continue to class, and rightly so, as belonging in many instances to the category of hysteria. It may be remembered that while admitting respiratory and bladder symptoms to the pithiatic class, the latter has excluded vasomotor, secretory, and trophic disturbances, since he has failed to reproduce them experimentally "in certain subjects." He cannot, of course, deny the frequent existence of vasomotor phenomena in hysterical cases, but he thinks it a mere coincidence. He does not see vasomotor symptoms more often in hysteria than in any other disease. In a very suggestible patient he has failed to evoke any vasomotor disturbance by means of suggestion. But this is not the experience of many hypnotizers, men whose good faith cannot be impugned for a moment. For the proven influence of suggestion upon menstruation, perspiration, the secretion of milk, the action of the bowels, &c., let the reader turn to Milne Bramwell's works, or to the accounts published by the Nancy School. There is no *a priori* reason why the vasomotor system should not be subject to functional alterations such as can be produced in these other systems by suggestion, and that these alterations are indirectly, if not directly, psychogenic there can be no doubt.

Let me support my contention with clinical instances.

A young woman, aged 22, was admitted to the hospital in a state of complete hysterical paraplegia. It was remarked that she trembled all over when she was addressed. When excited, even for no obvious reason, she would pant, sigh, breathe heavily and quickly; sometimes several short inspirations succeeded each other. The rhythm of her heart was at once disturbed if anyone spoke to her. There were very pronounced vasomotor phenomena; the legs were cold, blue, and mottled; she flushed very readily; her colour heightened and paled visibly. She presented characteristic hysterical symptoms—spasm of the tongue, absolute analgesia over the legs and one-half of the trunk, aphonia, &c. The legs were immobile and stiff, but if they were passively moved the stiffness disappeared readily by the simple device of diverting the patient's attention. There were no bladder symptoms, no bedsores, no alteration in electrical excitability, no muscular wasting, no change in the tendon reflexes, and a double flexor response. The analgesia was so complete that a needle was passed through the calf without its being perceived, and without causing any bleeding.

After a strong application of the wire brush the analgesia entirely disappeared, and where a minute or two before she had felt nothing she now felt the needle instantaneously; and in addition, *where formerly a vasomotor defect had prevented bleeding there was now bleeding whenever the skin was pricked.*

Without entering here into the minute analysis of this striking case, I may simply remark that it is a sin against nosology to classify the analgesia as hysterical, but to reject the vasomotor disturbance, for it came and went *pari passu* with the former. Of the psychogenic origin, directly or indirectly, of the vasomotor impairment I can entertain no doubt. The patient made an uninterrupted recovery, which has been maintained.

Another young woman with a neuropathic family history was admitted to hospital suffering from hysterical fits, hysterical tremors, and hysterical paraplegia. She was very emotional, had attacks of dyspnœa on the slightest provocation, and choreiform movements whose intensity was in direct proportion to the attention paid to them. Whenever anyone sat beside her bed she at once began to pant. Her analgesia was such that while I was examining her she snatched the pin out of my hand and drove it repeatedly into her right arm, and into her legs, remarking that she did not feel it unless it was driven in deeply. Janet's sign was elicited with the greatest ease over the thorax. The legs were absolutely immobile, bluish and mottled, and always cold. Passing a pin through the skin produced no bleeding.

Under appropriate treatment this patient made a complete recovery, and with the return of sensibility in the legs the vasomotor symptoms entirely disappeared.

There is no need to multiply instances, especially since so many observers are at one on this point. I can see no adequate grounds for the assertion that the mechanism of the production of the one symptom is different from the mechanism of production of the other; on the contrary, the likelihood of their having an identical origin is extreme.

The difficulty arises from the compulsion whereby Babinski must, for his theory's sake, refuse to recognize any symptom which is not the *exclusive* appurtenance of hysteria. He wishes to define not merely the characteristic symptoms of hysteria, but also the distinguishing features confined to that neurosis, and if we get vasomotor changes in other conditions, they cannot *ipso facto* belong to it. It is the artificiality of this method of procedure which has evoked a greater chorus of disapprobation than any other of the changes Babinski has introduced into the conception of hysteria.

The same observer, it is true, has published a case in which stimulation of the sole of the foot produced the phenomenon of "goose-skin" over an area on the antero-superior part of the right thigh. Without touching the skin, however, but by the simple remark that the "goose-skin" was about to appear, he has been able to make it appear. He thinks that its origin in suggestion is only apparent. Once the reaction begins it is under no control, and neither the volition of the patient nor of the observer can fix its site, form, intensity, and duration. But in a true case of hysteria, such as an hysterical monoplegia, the observer can control its form or duration at will.

It does not seem to me at all certain that the response of an hysterical patient to a suggestion can always be determined as far as the site, form, intensity, and duration of the reaction are concerned. And once the reaction takes place surely the volition of the patient has no influence on it.

(*c*). *Hysterical symptoms may arise in other ways than by suggestion.*

As has been once or twice mentioned in passing, Babinski attempts to minimize, if not entirely to explain away, the influence of emotion as a factor in the pathogenesis of hysterical symptoms, and as this is a matter of no little importance for his views it must be referred to with some minuteness. We must remember that even though a symptom does apparently arise as the result of an emotional shock, that is not evidence that Babinski might not be able to reproduce it with exactness in some other individual, hence it would come under the scope of his pathogenic standard; but as a matter of fact, he thinks the difficulty of excluding the action of suggestion or auto-suggestion, in connection with the appearance of any given hysterical symptom, so serious that it is the only mechanism, for all practical purposes, that he is willing to recognize, and as an offset to this he specifies the emotional factor in particular as being, in his opinion, negligible.

The apparent origin of hysterical phenomena in emotion is a circumstance of every-day occurrence. I was coming home one evening in a crowded tramcar from Buffalo Bill's Wild West Exhibition, and most of the passengers were somewhat elated by the rather exciting scenes of which we had been witness. A young woman seated opposite was, I noticed, particularly talkative and enthusiastic. Just as we were passing a certain house, someone in it accidentally set fire to the curtains, and in a moment the window was full of flame. Several of the passengers crowded to one side to look at it, while the young woman gave a shriek, and went off into one of the most typical hysterical fits I have ever seen. A simple illustration such as this will serve my purpose well enough, since we wish to subject the mechanism of the attack to scrutiny.

Babinski's first reply is that the spontaneity of the phenomenon is only apparent, inasmuch as the patient has probably seen something like it somewhere else, or has suffered from such attacks before, and is merely reproducing by suggestion, or rather auto-suggestion, what she has previously experienced. If we should be able to say, as of course I cannot in the particular instance I give now, that the patient had never consciously been witness of any similar attack before, then Babinski will reply that we cannot be sure she is not a mythomaniac who is feigning convulsions—an easy thing to do—in order to attract attention to herself. As a matter of fact, this drawing of attention to one's self is one of the characteristics of the hysterical temperament, as of the child's. I noticed at the time that the young woman sank, as if by accident, into the arms of a complete stranger (of the opposite sex) seated near her, whose embarrassment was as great as hers apparently was when she recovered. Hence we cannot prove that a fictitious element was wanting in the incident, but we do not thereby lose sight of the fact that emotion was the spark that produced the hysterical explosion.

Similarly with the cure of hysterical patients, under the influence of emotional stress, Babinski declares that the habit of assuring patients they will some day make a complete recovery is a form of persuasion which we may suppose has its due effect in time, and that when the hysterical paraplegic, bedridden for years, rushes *suddenly* from his bed on the cry of "Fire," it is permitted to conjecture that the thought of what has (perhaps) been so often told him by some odd association enters his mind simultaneously and exerts a therapeutic action. Hence it is not the emotion which cures, but the latent idea of cure. Whether the instinct of self-preservation is not more likely to assert itself than the idea of cure instilled laboriously, and only partially assimilated, is matter for discussion; "sauve qui peut" is a stimulus of greater potency, it seems to me, than "you will get better some day: oh, yes, you will get better"; and the plausibility or otherwise of Babinski's conjectural explanation must be left to the judgment of the individual. If he is dissatisfied, then Babinski offers another interpretation. According to him the *pithiatique* has to devote his attention subconsciously or unconsciously (the exact manner of this is not clearly explained by Babinski) to his paralysis, otherwise he is simply a malingerer, but an emotional shock will divert his attention, and he naturally recovers the use of his limbs; when the idea of powerlessness returns to his mind, he notes that for some moments at least he was able to move them, hence he is already persuaded of the possibility of a cure, which is all that is required to effect it. Assuming the psychological accuracy of this description, the explanation is feasible, and possibly some such mechanism might explain the case already quoted (p. 312), but why the influence of emotion should be ignored when, without its impulse, the patient's attention would never have been diverted at all, I am at a loss to understand. At the discussion, Pitres and Janet, among others, expressed the opinion that a simple, "cold," idea, devoid of affective concomitants, was not calculated *per se* either to provoke or to cure hysterical symptoms.

Pace Babinski, there are cases where hysteria develops independently of either suggestion or simulation. Various illustrations were given at the discussion, notably one by Dejerine, where a well-known scientist, as the result of a shock in a slight railway accident, developed unmistakeable symptoms of hysteria in a day or two. Let me quote one which has recently come under my observation, which has been examined especially in view of Babinski's contentions, and in which it seems to me only one conclusion is practical or even possible.

A woman of perfectly normal, good, general health, without any previous neurotic or neuropathic incidents worth remarking, was washing the stairs in her mistress's house one forenoon. These stairs were wooden and lead-covered at the edges, which were considerably worn. When walking down them, just after they had been washed, she slipped, struck her head and her back, and rolled down about seven steps till stopped by a turn in the stair. She was not unconscious. Her mistress heard the noise and came to pick her up, asking if she had hurt herself. The reply was, "I've hurt my back, I'm sure, and, I think, my head." The patient was assisted to her bedroom, and her mistress helped to undress her, and to put her to bed. Whilst this undressing was proceeding the patient said, "I must have fallen on my right hand; I can't feel it; it's all so numbed, and I can't unbutton properly with it at all." Her mistress agreed perhaps she had fallen on her hand, but said it would soon come all right again. While the patient lay in bed she kept feeling her right hand and arm with her left, and was certain there was something wrong which she could not understand. Her mistress came again to see how she was getting on, and took the affected right arm into her own hands to rub it. The patient said, "I can't feel what you are doing at all; I've tried lying on my arm to restore the circulation" (thinking it was a question of the circulation), "but it's no use." The mistress then took out a penknife from her pocket, and tried with the point of it, but her maid could feel nothing. At last the latter said, "I do not believe if I were to put my fingers into the door I would feel anything."

When this patient came into the hospital she presented the most exquisite symptoms of hysterical hemiplegia, subjective and objective, that can be imagined.

Now, in a consideration of this striking case, let the significance of the following points be duly estimated:—

The patient was in full normal health at the time of the shock, and had been up to the moment of the shock.

She had never shown any hysterical symptom before, and had not the slightest acquaintance with the disease.

She personally was as astonished as anyone at the immediate appearance of the phenomenon of numbness and loss of feeling, which she noticed while she was undressing, and attributed to "the circulation."

Her ignorance of its mechanism was complete.

She satisfied herself that she had lost feeling on that side before even her mistress, who knew nothing about medicine, tested her.

She was not seen by a doctor till some hours after the accident, when the phenomena of hysteria had already developed.

On objective examination she presented the typical features of hysterical hemiplegia.

Her symptoms are disappearing under the influence of persuasion.

A case such as this must be considered on its merits. It is entirely beside the point to quote Babinski's statement at the discussion: "On ne peut jamais affirmer qu'un malade n'a pas été suggestionné." As far as the most careful cross-examination can go, it must be acknowledged that no suggestive element could be discovered. I have every right to quote this case as one in which the action of suggestion, auto- or otherwise, can be excluded. Then why not freely admit that the shock produced the phenomena? Why not allow that they can come into being without an appeal to a hypothetical factor? Why strain the facts to fit the theory? If it is admitted, as I contend, with others, it must be admitted, that in some cases at least preceding suggestion in any of its varieties cannot be detected, then the absoluteness of Babinski's criteria vanishes, and his interpretation of hysterical symptoms becomes one possible explanation among other possible explanations, but no more. His views can in no sense be said to constitute an hypothesis of hysteria, comparable in the pathological field to the Darwinian hypothesis of evolution in the field of biology. The attribute or characteristic of hysterical symptoms vaunted by him as pathognomonic is not of universal applicability.

I do not know that we need delay over the arguments advanced by Babinski to minimize the importance of emotion or emotional shock as an element in the evocation of hysteria, such as its absence in the victims of the Messina earthquakes (in the Valparaiso earthquake hysteria did develop), or the rarity of hysterical outbursts on the part of visitors to the mortuaries of some of the big Paris hospitals. The circumstances in the latter case and in those where hysteria develops from an unexpected emotion are not comparable. Nor is it any refutation of the significance of emotion to insist that humanity is always swayed by the same passions, that the emotions of mankind do not change; that, accordingly, the frequency and form of hysterical affections ought to be always identical, under ordinary conditions, which they are not. Surely this is not advanced as a serious argument. It is a commonplace of observation that both the individual and the race vary enormously in their reaction to an emotional stimulus. Gustave le Bon remarks that in the eighties of last century the telegraphic announcement of an insignificant reverse at Langson provoked an explosion of fury in Paris and France, and brought about the instantaneous overthrow of the Government, whereas at the same moment a much more serious reverse undergone by our English expedition to Khartoum produced only a slight emotion, and no ministry was overturned. The traveller in Brazil will tell us that the two individuals who have drawn knives and seem in imminent danger of receiving the *coup de grâce* any moment are not sworn foes, but are merely discussing whether a certain street leads to the railway station, or away from it. The difficulty of deciding where to go and what to have for dinner may entail a similar performance on the part of two Italians. Why multiply instances? The response to an emotional shock will depend on the mental content of the individual, and because the stimulus is identical in any two cases its exteriorization in the guise of hysterical symptoms need not always, in fact cannot always, be the same in form and substance.

(*d*) *Babinski's views do not afford insight into the fundamental problem of the hysterical mind.*

"Suggestion" and "suggestibility" are words that come glibly to our lips in these days. They cover a multitude of diverse, and sometimes conflicting, phenomena. The field of suggestion is so wide that we can scarcely tell where the physiological ends and the pathological begins. The literature on the subject is bewildering in its extent. The public mind is permeated with the idea; it is part of the *soi-disant* scientific novelist's stock-in-trade. We must, however, essay a very brief *résumé* of our knowledge on the subject.

Suggestibility is normal or physiological in the case of the child. The younger members of a family sit round the study table in the evening and learn their lessons. One stammers slightly, intentionally or unintentionally, and is consciously or unconsciously imitated by the others. The imitation proceeds apace, if unchecked, until all are affected. One only, however, may become a confirmed stammerer, the others do not. Or, when books are put away they sit round the fire and make faces at each other; eventually one may develop a facial tic, the others do not. Imitation is essentially a form of suggestion, according to Babinski, and the children are all equally exposed to its influence. That some should respond more than others to its action can only mean that there are innate differences in their powers of inhibition. But even though all the members of the family should have developed tics or stammers, of longer or shorter duration, we should not have been astonished. Dubois observed an epidemic of hysterical chorea in a boarding school in Berne. Thirty girls were affected with articular pains and rhythmic movements of the arms, but isolation speedily cut short the attacks by reducing the facilities for imitation to *nil*. Dubois finds it difficult to believe that all were budding hysterical patients; "suggestibility has no limits in the normal mind of the child because of the insufficient development of the reason." Had the symptoms persisted in any particular case or cases, then we should find it necessary to postulate another etiological factor besides that of suggestion.

Intelligent adults can voluntarily allow themselves to be influenced by suggestion to a remarkable extent. It is the opinion of such authorities as Forel, Bernheim, Moll, Krafft-Ebing, that more than 75 per cent. of normal individuals are suggestible. Forel goes so far as to assert that every mentally healthy man is naturally hypnotizable. All experienced operators agree that the refractoriness of patients to suggestion is in inverse proportion to their sanity and strength of will. A normal individual can voluntarily submit to suggestion, as a child does involuntarily. In view of these facts, to which also Dr. Milne Bramwell says his experience bears abundant witness, it is our bounden duty to give up the notion that suggestibility is *in itself* a symptom of disease. To be suggestible and to be hysterical are not synonymous. The truth of these statements was emphasized by various speakers at the discussion, so that Babinski found it necessary to specify a *valeur péjoratif* to attach to the suggestion, whereby its acceptance on the part of the patient was pathological and not physiological. By this is meant that the suggestion is an "insinuation mauvaise." Yet it is exactly this "insinuation mauvaise" which the experienced hypnotist can produce in a large proportion of normal subjects. Crocq, Dupré, Ballet, Vogt, Dejerine, Dubois, and others, agree that suggestibility cannot possibly be utilized to describe sufficiently and exclusively the hysterical mind.[1]

We may be willing to grant, no doubt, that a peculiar susceptibility to suggestion is encountered more frequently in hysterical patients than in any other disease. They respond so readily to influences from without that the observer cannot fail to be struck by it. So universal is the experience that Babinski and others would raise the symptom to the pathognomonic level. But even where suggestibility is pathological, it is not *confined* to hysteria. The hysterical subject may be a prey to morbid self-suggestions, so assuredly is the neurasthenic. Dubois has abundantly exemplified the truth of this. In general paralysis, chronic alcoholism, Korsakow's psychosis, there is marked increase of suggestibility. I see little difference between suggesting to an alcoholic confined to bed that he has been for a drive round the park this morning, to which "insinuation mauvaise" he responds instantaneously by proceeding to describe what he saw and whom he met, and suggesting to a patient with hysteria that his arm is trembling, when he, too, will respond by evolving the required phenomenon. In each instance there is a reaction to a suggestion of extraneous origin without any application of the volitional brake on the patient's part. And similarly with other conditions that might be mentioned.

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[1] I cannot refrain from quoting one or two passages from the immortal Burton, which will serve to correct our perspective if we are inclined either to attach the merit of entire novelty to Babinski's views, or to doubt the universality of the action of suggestion and persuasion. Truly there is nothing new under the sun. "Men, if they see but another man tremble, giddy, or sick of some fearful disease, their apprehension and fear is so strong in this kind, that they will have the same disease. Or, if by some soothsayer, wiseman, fortune-teller, or physician, they be told they shall have such a disease, they will so seriously apprehend it, that they will instantly labour of it. . . . Dr. *Cotta*, in his "Discovery of Ignorant Practitioners of Physick," *cap.* 8, hath two strange stories, to this purpose, what fancy is able to do; the one of a parson's wife in *Northamptonshire*, *An.* 1607, that, coming to a Physician, and told by him that she was troubled with the *sciatica*, as he conjectured (a disease she was free from), the same night after her return, upon his words, fell into a grievous fit of a *sciatica;* and such another example he hath of another good wife, that was so troubled with the cramp, after the same manner she came by it, because her Physician did but name it. . . .

"As some are so molested by phantasy, so some again by fancy alone, and a good conceit, are as easily recovered. We see commonly the toothache, gout, falling sickness, biting of a mad dog, and many such maladies, cured by spells, words, characters, and charms; and many green wounds by that now so much used *unguentum armarium*, magnetically cured. . . . All the world knows there is no virtue in such charms, or cures, but a strong conceit and opinion alone. . . . The like we say of our magical effects, superstitious cures, and such as are done by mountebanks and wizards. An Empirick oftentimes, and a silly Chirurgeon, doth more strange cures than a rational Physician. *Nymannus* gives a reason, because the Patient puts his confidence in him, which *Avicenna prefers before art, precepts, and all remedies whatsoever.* 'Tis opinion alone (saith *Cardan*), that makes or mars Physicians, and he doth the best cures, according to *Hippocrates*, in whom most trust." (*Anatomy of Melancholy:* Part I, Sect. II, Mem. III, Subs. III. Shilleto's Edition, vol. 1, p. 295.) The magic of a name means as much to the hysterical patient to-day as thirty years since, or as in what we are pleased to call the Dark Ages.

If we grant, however, that exaggerated or pathological suggestibility is one, among others, of the characteristic but not exclusive features of the hysterical mind, that is to say, if we grant that hysterical patients do, as a matter of fact, respond more readily than others to suggestion, it must be obvious that they differ from ordinary individuals, as far as suggestibility is concerned, just in this matter of readiness of response; for, I repeat, the great majority of normal people can allow themselves to be influenced by suggestion, and therefore the mental state of the former must be such as to occasion the hypersuggestibility. Hence we are led to consider hypersuggestibility as a symptom and effect, rather than a cause of the mental state associated with hysteria. What is this peculiar mental state which has augmentation of suggestibility for a symptom?

We must look elsewhere than to Babinski's conceptions for the answer.

CHAPTER II.

Janet's Conception of Hysteria.

For twenty years and more the theory of hysteria enunciated and advocated by Janet has been before the medical world, which has had ample opportunities of testing his conclusions and criticizing the data on which they are based. Janet is not one of those who appeal to the results of therapeutic experience for confirmation of their theories, and he has himself acknowledged that there are certain hysterical symptoms difficult of explanation on his own hypothesis. His is a frankly psychological theory of the neurosis, according to which the somatic symptoms are the manifestations of underlying psychical disorders, which are characteristic of the disease. The student of the history of such an old-world disease as hysteria knows that the point of view from which it has been considered has varied greatly from one epoch to another, and if this point of view may be taken to be a reflex of the mental outlook of the age in which it has found an expression, then we should expect the twentieth century interpretation of hysteria to be sought in the realm of mind, for this is a time when many would assign all the ills to which flesh is heir to a pure disturbance of mind, and when psychopathy and psychotherapy are journalistic commonplaces. A majority of the modern conceptions of hysteria concur in the psychical "why" of hysteria; opinion is divergent on the "how." We shall see later the importance to be attached to the mechanism of the production of hysterical phenomena.

Now Janet has done no less and no more than any of his predecessors and contemporaries in the study of the hysterical problem; he has tried to discover some general distinctive marks with which to stamp the character of hysterical disorders. He believes he has found a common factor underlying the phenomena, however manifold they be, which may be expressed by the single word "amnesia," or, more generally, "absent-mindedness." From the simplest hysterical disturbance of sensibility, or motion, to the most elaborate hysterical fugue, this element of amnesia may be traced in all.

Instead of making a commencement with the familiar signs and stigmata of the disease—the palsies, contractures, and anæsthesias of the text-books—Janet takes the hysterical fit or convulsion as presenting in its simplest form the amnesia which is the essential psychological abnormality of the neurosis, and passes therefrom, by easy gradations, to the complex hysterical fugue on the one hand, and the elementary loss of sensation on the other. The change our nosological conceptions of hysteria have undergone since the days of Charcot is nowhere more apparent than in the way in which the systematization of the outward expression of the hysterical fit has been subordinated to a searching analysis of the psychical substratum. Scan the pages, study the beautiful drawings, of Paul Richer's "Hystéro-epilepsie," and then, when mind and eye are almost bewildered by the diversity of the phenomena, remember that there is an underlying unity in the common factor of amnesia. Indeed, since many "attacks" have nothing convulsive about them, Janet adopts the term "hysterical somnambulism," to exemplify the type of seizure which illustrates his views. Under the stress of some emotional shock, at the bidding of some imperious but not consciously appreciated impulse, the hysterical patient falls into a half faint, a reverie, and loses touch with his immediate surroundings; his voluntary activity comes to a standstill; the somnambulism has already commenced. He lives some scene over again; goes through some action, amounting often to a sort of "performance," with quickness and precision; he gives himself up to the thraldom of some idea, and obeys it to the exclusion of all others; stimuli from without do not reach him by the ordinary avenues of sense; he is in a dream, he is living for the moment in a microcosmos, which is the sum of his memories and sensations for that time.

When he comes back to consciousness, when he recovers his full personality, as represented by the sum of innumerable memories and sensations, he has utterly forgotten the scene which he has just enacted; it is out of his consciousness, and has apparently left no trace behind. Yet, should the exciting cause of the somnambulism reappear, he will inevitably sink into the former state, and repeat the performance to its minutest detail.

Such is a "monoideic somnambulism," a psychical state consisting in the detachment of a small system of interrelated ideas from the infinitely greater complex of ideas, whose coherence constitutes the individual's personality or entire consciousness; this system of ideas, set free and developing on its own account, in the absence of inhibition, becomes for the time being dominant. With the return of normal consciousness, not only is this disaggregated or dissociated system forgotten, but in the majority of cases the idea which awakened it into activity is also forgotten; in other words, the amnesia is retrograde.

Polyideic somnambulisms and hysterical fugues are but transformations or elaborations of the simpler variety. A system of images with subsidiary systems in association is separated from the totality of consciousness, in which it leaves a blank, represented by an amnesia; once it is emancipated, once the mechanism is set going which liberates it, it develops on its own accord; by association one system after another is aroused, and so on almost indefinitely. Let me give a concrete instance to illustrate Janet's hypothesis.

A young man came into hospital with a history of fits, the exact nature of which had not been determined. One of them observed during his stay in hospital was of the following description: About 8.30 p.m., one evening, he said he was going to have a fit. When we reached him he was lying on his back in a cruciform attitude, his hands firmly grasping the edges of the mattresses (which were on the floor). He was breathing in rapid gasps, with an occasional short grunting cry, as of painful effort. His head was bent backwards, and his back arched. All the movements he made were definitely purposive. He recovered in a minute or two, and was quite rational, but immediately thereafter he became stiff in the trunk, stretched out his arms again as before, feeling for the edge of the mattress; the head went back, and the back arched. Then the movements became confused, and he turned and twisted in various directions. This sort of thing was repeated three or four times, after the last of which he cried out something like "Goodbye, goodbye!" and suddenly, while on his back, began to give military commands. "Form fours. . . . Right!" "Double up with those machines there," and so forth—all given loudly and accurately, and with a good word of command. (The patient was an officer of the volunteers, and had drilled a cycle corps.)

After this he rose to his knees and began to put up his hands as if boxing. He came for us, who were looking on, as if he saw us, but did not rise from his knees—striking with both hands in very good style and with great force, but without any precision. He hit his fists hard against the wooden partition of the cubicle, inside which the "performance" was being held. He repeated all this about three times, then lay still.

Then, from where he lay, he suddenly began to give hunting cries in a loud voice and realistic manner. "Harmony! Harmony! Harmony!" "In at 'em! . . ." "Hoick! Hoick! . . ." "Gone away! Gone away! . . ," &c. (He had been fond of hunting, in particular of otter-hunting.)

Then he mentioned some man by name, and talked of a girl of his acquaintance, rattling on somewhat as follows: "———, you blackguard. As soon as your sister's out of the room you begin to talk like that. You are a scoundrel, a damned scoundrel. . . . No, I daresay you don't like it," &c. He then became quiet again, and in a minute or two was in a normal state. He had no memory of the details of his little rehearsal.[1]

Janet's explanation of the psychological mechanism of such elaborate attacks affords much insight into their character.

When we proceed in the direction of the less complex phenomena of hysteria, we learn that a large number of minor attacks and *crises* are nothing else than imperfect somnambulisms. There is order behind the apparent disorder of the hysterical attack; the movements are subjectively purposeful, however purposeless they may objectively seem. The young woman who falls full length on her bed as the physician enters the ward to make his round, and lies there with quivering eyelids and shaking limbs, sighing and panting, her arms extended in cruciform attitude, is not a puppet or a mechanical doll; there is method in her madness; she is an actress, but she does not know that she is acting. Fifty years ago Briquet wrote that a fit of simple hysteria is nothing but the exact repetition of the disturbances by which vivid and painful moral impressions are manifested, and in many cases it is possible to distinguish and recognize the particular emotion that finds expression. In other words, a dissociated idea or system of ideas establishes itself, to the exclusion of all others, in an emotional form, in a cruder and coarser fashion than in the seemingly intelligent action of the somnambulism.

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[1] This description is taken in part from the notes of Dr. Carmalt Jones, who was one of the house physicians at the time and witnessed the attack.

Janet further illustrates his general principle that amnesia or absent-mindedness can be traced in all hysterical phenomena by a consideration of the familiar motor and sensory symptoms, the tremors, spasms, contractures, and palsies, the anæsthesias, hyperæsthesias and *points douloureux*. We cannot follow his lead through them all, and Janet's views are familiar enough to the neurologist. Suffice it to say that the will of the subject has no influence on these symptoms, and that consciousness does not seem to have a great hold on them either. Some function or functions, such as that of moving the arm or the leg, is separated from consciousness, and motor activity, disaggregated in this way, may assume various forms. On the sensory side, the *ensemble* of sensations coming from the arm or the leg form a kind of system which can no longer be connected with the totality of consciousness, although it still exists on its own account and may even determine reflexes and ordinary movements. Hysterical anæsthesia is essentially a species of absent-mindedness. There is in it a pathological incapacity on the part of the patient to connect with his personality the sum of the particular sensations concerned. A similar explanation may be furnished for the impairment of the special senses so frequently encountered. A *résumé* of the conclusions to be drawn from Janet's investigations is supplied by himself in a form somewhat as follows:—

"Hysteria is a disease of the mind and belongs to the large group of maladies occasioned by cerebral depression or exhaustion; its physical accompaniments are vague enough, consisting chiefly in a general diminution of nutrition. It is characterized principally by mental symptoms, of which the most important is impairment of the faculty of psychological synthesis, an aboulia, or constriction of the field of consciousness, manifesting itself after a special fashion; a certain number of elementary phenomena of motion—sensations and images—cease to be perceived and appear to be excluded from full conscious personal perception: hence there is a tendency to a permanent and complete division of personality, and to the formation of several independent groups. These psychological systems either alternate or co-exist.

Finally, the defect of synthesis favours the development of certain parasitic ideas which evolve by themselves and in their entirety under cover of the control of personal consciousness, and which manifest themselves in markedly variable disturbances in appearance solely objective."

The conception has been put more briefly in Janet's latest work, and is there couched in the following terms:—

Hysteria is a form of mental depression characterized by the retraction of the field of personal consciousness, and a tendency to the dissociation and emancipation of the systems of ideas and functions that constitute personality.

We shall better understand the full meaning of this condensed statement if we take a glance at Janet's analysis of the hysterical mind. He has replaced the classical stigmata of Charcot by others of a totally different nature, psychical and not physiological. These new stigmata, however, Janet is careful not to endow with any attribute of absoluteness, although some are, in his opinion, scarcely to be found in any other condition than hysteria. It is impossible, even if it were desirable, completely to isolate or insulate the neurosis under consideration from all other neuroses; yet it is, of course, a special form, and can be more or less distinguished from the rest. Of the stigmata that characterize the hysterical mind there are two groups:—

(1) *Some are common to Hysteria and to other Mental Disturbances.* Hysterical patients are neuropaths first of all. They reveal a curious combination of emotionality and of apathy; they are both sensitive and indifferent. They must needs attract attention to themselves, yet they evince no aptitude for attention; they lapse into reverie; they are often unable to retain recent impressions. What Janet has called "feelings of incompleteness" are frequently met with in hysteria; the patients "are perpetually tormented by a vague ennui which they cannot overcome." Among other defects of mental function disturbances of the will occupy an important place. Inability to will, to begin a particular action or to inhibit it once it is begun, is universally recognized as a common feature of hysteria, as much so as of psychasthenia. One of Janet's patients put it very neatly: "I fall into an idea as down a precipice, and the declivity is hard to climb again."

The general result of these defects, not exclusively characteristic of hysteria, however frequent their occurrence in that neurosis, is a lowering of the mental level, a form of mental depression.

(2) *Some appear to be proper to Hysteria.*

(*a*) *Suggestibility.* — I have already remarked that consensus of medical opinion assigns to suggestibility a place of paramount importance for the development of hysterical phenomena. That it should be proclaimed the sole criterion whereby to judge hysterical symptoms is not feasible from a practical standpoint, and is psychologically untenable. We willingly grant, however, as I have shown, that there is a pathological suggestibility highly, though not absolutely, characteristic of hysterical states. The feature of this abnormal suggestibility is that the idea which is suggested develops to an extreme, without participation either of the will or of the personal consciousness of the subject. Janet himself holds that the term suggestibility should be restricted to this pathological variety, and he agrees with Babinski to some extent on this point. As the latter has said, it is a matter of terminological convention whether suggestion is to be applied solely to the form that has just been mentioned. Be this as it may, it is unnecessary to repeat here the objections previously urged to the view that considers pathological suggestibility a unique feature of the hysterical mind. What is much more important is to appreciate the fundamental difference of attitude between Babinski and Janet in the discussion of the significance of suggestion. Janet's position is that this suggestibility is itself dependent on another factor. If an individual reacts blindly to a pathological suggestion, it is because he is no longer capable of controlling, investigating, deliberating on the ideas presented to him. A *sine qua non* for the fruitful development of a suggestion is the absence from the patient's field of consciousness of ideas antagonistic to the suggestion. As Janet says, its strength rests on the astonishing ignorance of the patient. Objections, impossibilities, contradictions, do not reach his mind. Thus suggestibility is an effect, not a cause: "absent-mindedness" allows it, and precedes it.

(*b*) *Absent-mindedness* is the second feature of the hysterical mind. There is a suppression of all that is not looked at directly. We have already seen how intellectually satisfying is the explanation by amnesia or absent-mindedness of so many of the diverse symptoms of hysteria, and need not enlarge further on the subject in this place. What we must note here is simply the logical extension of the hypothesis, so that suggestibility itself is included among the symptoms dependent on amnesia.

(*c*) Another characteristic of the hysterical mind, according to Janet, is the tendency to *transfers* and *equivalents*. No one with any clinical experience of hysteria but has been struck by the alternation in symptoms so frequently met with. It would be superfluous to cite instances of so banal a phenomenon. One symptom disappears only to be succeeded forthwith by another. Janet thinks there is something peculiar to hysteria in this special form of instability, although sudden alternation in symptoms is by no means unknown in other conditions. I have seen spasmodic torticollis alternate, by periodic transitions, with delusional insanity. When the patient was insane there was no torticollis: her intervals of complete sanity, on the other hand, were accompanied by the wryneck.

These characteristics of the hysterical mind may be summarized into a single general idea, to express the fundamental element in the psychoneurosis, viz., "retraction of the field of personal consciousness." This brings us back to our definition already quoted, so that we have learned the steps by which Janet has reached it.

If the field of personal consciousness be thus restricted it is not to be imagined that all impressions not reaching it, not synthetized with it and made a part of its content, are lost. On the contrary, they reach and produce their due effect in a secondary or subsidiary consciousness, which is a necessary postulate for a complete psychological explanation of Janet's conception of hysteria. Thus consciousness is regarded as being split or doubled; and we are at once introduced to the multitudinous and complex phenomena of the so-called subconscious mind.

It is true the extent to which the psychological conception of a subconscious mind has been enlarged is scarcely credible: to its activities are ascribed our virtues and our failings, our inspirations and our enthusiasms: it is the source of inventive genius: it is the means whereby God speaks to man: subconscious telepathy and the Communion of Saints are synonymous terms, &c., &c. The old Scottish advocate, who on the night before his cases came up for decision, used to read over his briefs to the accompaniment of copious draughts of his national beverage, and who attributed his success to letting everything "whummle in his wame" during the night, had not heard of the subconscious, probably, else his theory might have been expressed more scientifically, though not necessarily more lucidly. Janet quotes an amusing saying of Hartmann: "Let us not despair at having a mind so practical and so lowly, so unpoetical and so little spiritual: there is within the innermost sanctuary of each of us a marvellous something of which we are unconscious, which dreams and prays while we labour to earn our daily bread." It is quite beyond the purpose of this rapid review even to mention the various theories of the action of the subconscious mind, or to delay where hysterical phenomena are concerned by endeavouring to supply an interpretation based on that action. It is sufficient, and at the same time it is only fair to Janet to state, that he expressly confines himself to a purely clinical, and, as he says, somewhat prosaic, use of the word "subconscious." He employs it to characterize perfectly commonplace phenomena, with which all students of hysteria are familiar. An hysterical patient, with an arm and hand completely insensible to all forms of cutaneous and deep stimuli, will, if the observer put a screen in front of the patient's eyes, and then impress a series of alternating flexion and extension movements on a particular finger, nevertheless continue to make two or three movements with his finger after the operator has ceased. That the finger should spontaneously repeat the movement, the latter must have been perceived. Yet the patient insists that he felt absolutely nothing. A psychomotor act has been performed without the patient's conscious knowledge: it is a subconscious phenomenon. The mental processes involved are disaggregated from the conscious personality of the patient: they are for the time "on their own."

Take a second illustration of a rather different sort. Some years ago in a little village in the Harz Mountains I witnessed a performance by "La Madeleine," who, as her professional descriptive title of "Schlaftänzerin" indicated, danced to music while she was in a state of hypnosis. It was easy to satisfy oneself that the performance was genuine, as opportunities were afforded medical men of examining her when she was in this state. As the music rose and fell, or changed from sad to gay, quick to slow, passionate to soothing, so La Madeleine altered her steps, her rhythm, her gestures, in perfect harmony, at length ceasing abruptly ere the pianist had finished. She heard and perceived the auditory impressions and responded to them intelligently, while at the same time she was completely unaware of what she was doing. The sensory stimuli were not connected with, or merged in, her personal consciousness. It is to phenomena such as these that Janet applied the term "subconscious"; he offers no theory of subconscious mechanisms, be it noted, but simply utilizes the conception to complete his psychological interpretation of hysteria.

Janet's interesting and attractive opinions are, I believe, as far as they go, the most satisfying of the various psychological explanations of the disease that have been proposed. They serve better than any other to bring into relief the essential nature of hysterical disorders.

Whatever alterations in our ways of regarding the neurosis subsequent investigation may effect, it cannot be considered as other than a disease of the highest or psychical level. At this stage of our knowledge it is like sending owls to Athens to cite instances in support of this contention, yet I may be allowed to quote briefly one or two little incidents of clinical observation that have to me been very instructive.

A young woman came into hospital with an hysterical monoplegia of the left leg. There was complete insensibility to stimuli of cutaneous origin over the skin from the knee down. So absolute was this insensibility that a pin could be passed through the skin without her feeling any pain. When I produced a Cattell's algometer, an apparatus of the nature of which she was in ignorance, and pushed it into the left calf, to my astonishment she cried out with pain when the instrument had only registered 4—a normal response. On testing her skin condition again, the anæsthesia had disappeared.

One may suppose that the patient had a certain mental image of her left leg, compounded of various secondary sense memories and images. This mental image or system was for the time being dissociated from the patient's totality of systems, constituting her conscious personality. Hence she felt no pain when the leg was stimulated. As, however, there did not happen to be included in this disaggregated mental picture of her limb the element belonging to deep sensibility, whenever a stimulus reached the underlying tissues she felt it instantaneously, and with it the mental image of the limb returned to conciousness.

How can we explain, except on the view that hysteria is a disease of the level of mental images, the loss of sensibility in a case of hysterical paraplegia, where the analgesia on the back of the trunk completely differed in distribution from the analgesia on the front?

Take a still more remarkable instance.

A woman came into hospital with a complete left hysterical hemiplegia and hemianæsthesia, and impairment of all the special senses on the left. The hemianæsthesia was absolute to every form of stimulus, cutaneous and deep. In addition, the patient exemplified admirably the phenomena of so-called "Seelenlähmung"; she could not move her left arm or leg unless her eyes were open and she was looking at it. On the right side of the body there was normal sensibility throughout. When her right arm was passively put by the observer behind the patient's head, so that the right hand and part of the forearm were to the left side of the mid-line of the patient's body, she lost sensibility in that part of the limb which was to the left. It is true there was no sharply demarcated line corresponding strictly to the mid-line of the body; it was, however, the case that if the hand or fingers were well to the left, behind the patient's head, then they became insensitive.[1]

The reader will appreciate the ease with which an explanation of this extremely interesting observation can be offered on Janet's hypothesis. The disturbance of the idea of "sidedness" is an indication of the psychical level of the disease.

While Janet's hypothesis is inherently reasonable and his masterly exposition of it very convincing, there are certain symptoms of hysteria and certain types of cases to which its application is not altogether easy.

(1) Cases in which hysterical symptoms suddenly arise, after a trauma, are difficult of explanation, inasmuch as the relation of the trauma to the subsequent appearance of the symptoms is not at all obvious. If we take the case already instanced (p. 320) to show the absence of the factor of suggestion, I do not see that we learn anything as to the *causa causans* by saying that the field of personal consciousness is constricted, and the system of ideas relating to the right side of the body is no longer synthetized with it. In such cases the psychological explanation may be perfectly correct, but is it a *pathogenic* explanation, or is it not rather simply a description of the psychological accompaniments of the somatic phenomenon? In any case we learn nothing from Janet's theory as to why and how a trauma should suddenly produce an hysterical hemiplegia.

Similarly, there are many cases where hysterical symptoms appear without any evidence of any mental factor being at work.

A nurse, fatigued by overwork when on night duty, noticed one evening that her voice was husky, and the next morning found, to her surprise, that she was completely aphonic. She presented no other symptom, and had always been perfectly able to do her work. On objective examination the characteristic appearance of the vocal cords was found; they moved perfectly well and met in the middle line, in complete apposition, during a sudden retching spasm. A single application of faradism to the outside of the neck resulted in the immediate disappearance of the symptom, and effected a lasting cure. *Naturam morborum curationes ostendunt.*

In this monosymptomatic case there was no trace of any suggestion to be discovered, nor was there any indication to aid us in explaining its pathogenesis. How are we to attempt to elucidate this hysterical aphonia? I do not doubt that Janet's hypothesis supplies a clearly thought out explanation of the psychological features of the condition, but I can find no proof or sign of the existence of that hysterical mind which is the soil from which the symptoms are supposed to spring.

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[1] This observation was originally made, I believe, by Dr. Foster Kennedy, then Resident Medical Officer, and I had opportunities subsequently of observing the phenomena for myself.

In fact, a wider objection has been raised applicable to all purely psychological theories, that one may be as correct as another in the explanation of any given case. Thus the above-mentioned patient may have been aphonic because she had a fixed idea that she could not speak above a whisper; or because she was aboulic, and could not will to speak; or because her attention was distracted from her voice; or because she was suffering from systematized anæsthesia; or because she had forgotten the representations and memory images for the movements of phonation; or because voicelessness was suggested to her, or auto-suggested; or because of the constriction of her mental horizon, so that she could not combine in one personal synthesis the sensations concerned; or because this system of impressions and representations was actually dissociated from personal consciousness.

It is true, no doubt, that any one of the above explanations may hold good in a given case. Moreover, we may be quite unable to decide between several of them, in connection with another case. The advantage of psychological theories is that any or all of them may be correct. But the fact does not invalidate the general position. They are evolved to offer interpretations of objectively observed data, and as by their inductive nature they are incapable of proof or disproof—for an induction is always debateable in the strict sense—we must choose that one with which the facts seem best to accord. Janet's views are condensed into an inductive generalization, an hypothesis, using the word scientifically which hypothesis we utilize to explain certain clinical phenomena, and we find it both reasonable and of wide application. It matters not that a totally different psychological explanation may be advanced in regard to any particular symptom or case of hysteria both may be true, but we cannot conceive of both in action in one and the same case. Sollier's criticism that no psychological explanation of the symptoms of hysteria is really pathogenic is immaterial; we believe in the duality of mental processes, and cannot imagine hysteria to be a disease *sine materie.* In the present state of our knowledge it is futile to attempt any correlation of psychology and physiology; therefore we are not concerned to discuss whether, for instance, the idea of a doubling of consciousness, or the conception of a constricted mental field, is the sequel to, or the accompaniment of, some physiological state of association neurones. It is sufficient that the conviction of the essentially ideogenic origin of hysterical phenomena demands, for our own intellectual satisfaction, a theory of the disease that is expressed in psychological terms; we do not thereby sacrifice all interest in its physiological aspect; all we say is, that speculation at present is bound to remain unproductive. Féré's objection to a psychological theory, that it hinders all search for a physical one, need not alarm us. We do not believe in a disease confined to the world of ideas; it must have a counterpart in the physiological world—what that may be must be left for future investigation.

(2) Vasomotor, nutritional and trophic disorders, such as are frequently found in connection with hysteria, are difficult to explain on Janet's hypothesis. A consideration of this point, however, and of a further objection, viz., that the hypothesis is unnecessary in certain cases where organic and hysterical disease occurs in the same patient, for often no ideogenic factor can be traced, must be left for another occasion.

I have repeatedly said that I believe we must depend on the objective signs of hysterical disease if we are to progress towards its unification. Janet himself holds that the intrinsic examination of cases of hysteria is the most accurate and scientific method. Now the chief point, as it seems to me, on which more light is wanted, is the *mechanism of the production of the symptoms*. Granted that a particular mental state is accountable for the disturbances of function, how are these actually brought into being? Granted that amnesia or absent-mindedness causes hysterical motor defects, why have we tremor in one instance and paralysis in another? And what are the objective features of these? Can we thereby learn anything as to the seat of the functional defect? I am convinced from the study of a number of cases that organic disease will teach us far more about hysteria than *vice versâ*. Thus I observe a case of thrombosis of part of the medulla, and I discover that the anæsthesia and vasomotor changes consecutive to this thrombosis are in some ways extraordinarily like what is met with in hysteria. I find that the tremors, spasms, and palsies of hysteria are characterized by a certain functional defect on which much light is thrown by recent physiological research on the functions of the cerebrum. I come across cases of disseminated sclerosis with symptoms indistinguishable from those of hysteria. I observe a case of pure hysteria in which micropsia is one of the symptoms, and I compare its objective features with micropsias of known organic origin. The objective study of the symptoms of the neurosis must continue to be our task; hysteria, however psychical its background, reveals itself by somatic symptoms and signs as definite and real as those of general paralysis. I hope to return to a consideration of some of these questions, which concern the mechanism of hysterical symptomatology, and the opportunity will be taken to refer to the relation of Janet's hypothesis to them.

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FREUD'S CONCEPTION OF HYSTERIA.

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I.—INTRODUCTORY.

THE system of psychology founded by Professor Freud, of Vienna, has during the past few years aroused a widespread interest. His doctrines have met with every variety of reception, ranging from an enthusiastic acceptance to an uncompromising and complete rejection. Whatever the ultimate verdict of science may be, the problems involved are of such undoubted importance that all will be agreed as to the desirability of a thorough investigation of Freud's theories and an accurate determination of their claim to scientific validity. An exhaustive inquiry of this kind is, however, altogether beyond the scope of the present review; it aims merely at the presentation, in a short and summary form, of Freud's main doctrines concerning the nature and etiology of hysteria. No attempt will be made to give in detail the evidence upon which these doctrines are based, nor to criticize the various arguments which have been advanced for and against them. It is hoped, however, that the review will serve as an introduction for those who are at present unacquainted with Freud's work; and that the extensive bibliography which has been appended will be found useful to those desirous of investigating the subject in a more complete and satisfactory manner.

Although Freud's researches were originally confined to the domain of hysteria, they have since been extended to many other problems of normal and abnormal psychology. These extensions lie outside our main theme, but they are so intimately allied that occasional reference to them cannot be avoided. For the same reason, it has been thought advisable to include in the bibliography most of the works of Freud and his followers, although some of these have only an indirect bearing upon the phenomena of hysteria.

During his long career, Freud's views have on many points undergone a considerable change. He has never, moreover, published a complete and systematic exposition of his theories as they stand to-day. For these reasons most reviewers have elected to describe his psychology along the lines of its historical development. It is believed, however, that the systematic method gives the subject a more easily understandable form, and it will therefore be adopted in the present review.

The adoption of the systematic method has involved two consequences. Firstly, on account of the magnitude and complication of the subject it has been necessary to present certain sections in a perhaps unduly simplified form, in order that the logical connexions between the successive portions may be clearly brought out. Secondly, it has been thought advisable to describe certain fundamental doctrines from a point of view more general than that found in Freud's own writings. This applies more especially to the section dealing with the theory of complexes.

II.—Historical.

Freud was a pupil of Charcot, and therefore early became acquainted with the French School of Psychology. The fundamental principles of that school, the insistence upon the psychological method in the investigation of the psychoneuroses, and the conception of dissociation of consciousness, have played an important part in the development of Freud's views. The starting point of his psychological career, however, may be said to have been the moment when he became acquainted with certain observations made by J. Breuer on a case of hysteria, and with certain tentative hypotheses which the latter proposed as a result of those observations. Freud became associated with Breuer in the investigation of similar cases along similar lines, and their combined work led finally in 1895 to the publication of the well-known "Studien über Hysterie" [38]. Subsequently the partnership was dissolved, and Freud continued his researches alone. He has since produced numerous works dealing with various problems of normal and abnormal psychology, of which the most important are "Die Traumdeutung" [70] and "Drei Abhandlungen zur Sexualtheorie" [75], published in 1900 and 1905 respectively.

For a long period Freud's theories aroused but little interest, and he was almost the sole worker in the field which he had opened up. Latterly, however, the literature dealing with the subject has multiplied in a remarkable manner, and Freud's system of psychology has become one of the most important and acutely contested questions in the world of modern science. This extension of interest is to be largely ascribed to the work of the Zürich School, headed by Bleuler and Jung. The production of Jung's "Diagnostische Assoziationsstudien" [149] and "Psychologie der Dementia præcox" [160] has exerted a particularly potent influence in this respect.

III.—FUNDAMENTAL CONCEPTIONS.

The fundamental presuppositions upon which Freud's work is based may be said to be two in number—the doctrine of psychological determinism, and the doctrine that mental phenomena are capable of a *psychological* explanation without reference to processes occurring in the brain. According to the first, mental processes are rigidly subjected to the law of causation; no mental event is undetermined and due to chance. Without this presupposition it is obvious that no science of psychology can exist. According to the second, it is possible to explain mental processes by scientific laws involving *psychological* terms only.

In his endeavour to discover laws of this nature Freud has found it necessary to assume the existence of psychical processes of which the individual himself is altogether unaware. This is the conception of the *unconscious*, which plays a prominent part throughout the whole of Freud's psychology. It is impossible to enter here into the philosophical justification of this conception and of the preceding postulates; the reader must be referred to two former papers by the present reviewer, in which the question has been discussed at considerable length [111, 112].

IV.—THE THEORY OF COMPLEXES.

A "complex" is a system of ideas possessing a certain emotional tone and conative trend—that is to say, it tends to generate thoughts or actions leading in some definite direction. A complex may therefore be regarded as invested with a certain amount of energy, which can only be discharged efficiently by the attainment of a definite end. This process of efficient discharge, which is termed by Freud "abreagieren," leads to an end state of satisfaction (*Befriedigung*).

The meaning of this conception will be made clear by taking as a simple example the familiar case of the lover. His thoughts and behaviour exhibit certain characteristics which we should ascribe, adopting Freud's terminology, to the fact that he is dominated by a "love complex." Ideas belonging to the complex incessantly emerge into consciousness, the slightest associative connexions sufficing to arouse them. All his mental energy is absorbed in weaving trains of thought centred about the beloved one, so that he cannot divert his mind to the business of the day. Every event which happens is brought into relation with his passion, and the whole universe is considered *sub specie amoris* [160]. This condition persists until "abreagieren" is attained by possession of the desired individual.

It will be seen that complexes are the forces which determine the direction and content of the conscious stream. They may be regarded, in fact, as the psychological analogue of the conception of "force" in physics.[1] Freud's system of psychology is an endeavour to explain the course of consciousness as a result of the action and interaction of various complexes.

A complex is not continuously active; it only becomes so when it is "stimulated" in some way. This stimulation occurs whenever one or more of the ideas belonging to the complex are roused to activity, either by some external event or by processes of association occurring within the mind itself. The complex will then immediately tend to exert its effect upon phenomenal consciousness. The effect consists normally in the introduction into consciousness of the various constituent ideas and trends of thought and action belonging to the complex. Mental processes in harmony with these trends will be reinforced; those not so in harmony will tend to be inhibited and to lose their force. All these points can be illustrated by the suggested example of the lover.

It must be observed that the individual himself may be quite unaware of the nature of the complexes which actually determine the direction of his thought. Thus, if a new measure is laid before a party politician, his verdict will be largely determined, not by the absolute merits or demerits of the measure in question, but by the fact that it was introduced by his own or the opposing party. He may, nevertheless, honestly believe that he is actuated entirely by a dispassionate consideration of the logical pros and cons. In ordinary language we should say that the politician was "unconsciously biased" in the language of Freud we should say that his judgment was the result of a "political complex" of whose action he was himself unconscious.

The doctrine that a man is frequently ignorant of the real psychological causes which determine his own thoughts and actions—a doctrine known implicitly to every competent novelist and historian—must be clearly recognized by any psychology which claims to be in touch with reality. The importance and fruitfulness of this conception cannot be over-estimated, and its precise formulation constitutes one of Freud's greatest services to science.

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[1] A complex is not, of course, a phenomenal constituent of the mind, but a conceptual abstraction belonging to the same category as atoms and ether waves [112].

V.—CONFLICTS.

If two or more complexes, tending to produce effects which are out of harmony with, or even in direct opposition to, one another, are simultaneously present in the mind of the individual, then the result will be a state of "conflict." The complexes will mutually inhibit each other, and the mind is, as it were, divided against itself. A condition of unpleasant emotional tension ensues, which persists until the conflict is solved. The conception of conflict may be illustrated by an adaptation of our former example of the lover. Suppose that the object of the latter's passion is already the wife of another man. The lover's mind will then exhibit two complexes trending in opposite and incompatible directions—on the one hand the desire for the woman, on the other the opposing tendencies constituted by moral education and fear of consequences. Under such circumstances neither is able to express itself freely in appropriate action, and a state of conflict results.

The solution of a conflict may be attained in many different ways. For example, the complexes may become modified so that the incompatibility no longer exists, or the mind may clearly recognize that the two ends cannot both be attained, and that one must be abandoned in favour of the other. Certain modes of solution are, however, definitely morbid, and it is in these latter modes that Freud sees the causation of the symptoms of hysteria and other psychoneuroses.

VI.—REPRESSION AND CENSURE.

The conflict may be avoided by banishing one of the opposing complexes from the mind, and striving to forget its very existence. If this process is successful a condition of "repression" (*Verdrängung*) is attained. The repressed complex is thereby deprived of its power of influencing phenomenal consciousness in a normal manner; that is to say, its constituent ideas can no longer emerge into consciousness without resistance, and it can no longer cause the flow of thought and action to proceed in the direction of its own conative trends. It does not cease to exist, but becomes "unconscious" in the peculiar sense which Freud ascribes to the word.[1] So long as the repression causes the complex to remain in the unconscious its component ideas are excluded from the field of consciousness, and cannot enter into the normal play of associations. The most important result of this state of affairs is that a normal "abreagieren" or discharge is altogether prevented, and the complex energy can find no efficient outlet.

Freud conceives that the ideas belonging to a repressed complex are prevented from entering into consciousness by the action of certain resistances to which he has given the name of "censure" (*Zensur*). The conception of censure simply expresses the fact that a state of repression is only preserved by an active process which is constantly functioning. This process is, of course, of the same nature as that by which the repression was originally achieved and the mind relieved of its conflict.

A further variation of the lover example may be used to illustrate what is meant by repression. "Suppose that a young man, dependent on a rich father, falls in love, and that the object of his choice meets with the father's strong disapproval. In his despair the thought may occur to him that were his father to die all would go well, and, to his horror, he finds himself playing with this thought in his imagination, and even for a moment half wishing its consummation, or, at all events, not being prepared to regret it as conscientiously as he considers he should. A normal man under these circumstances would honestly recognize the existence of the wish in him, though he would, of course, realize that for pious and ethical reasons it would obviously have to be suppressed; this would probably be an easy matter, for the ethical part of his personality to which the wish is inacceptable would evidently be stronger than the part corresponding to the wish. A neurotic, on the other hand, is more likely to react towards such an occurrence by not owning to himself that he ever had such a wish, even momentarily, and by striving to get away from such an unpleasant thought, to forget, or repress it" [140]. That is to say, one of the two opposing complexes is thrust out of consciousness, and is therefore unable to work itself out in a normal manner by assimilation into the personality as a whole.

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[1] Freud divides mental processes into three classes: (1) The *Bewusstsein*, comprising the mental phenomena which the individual actually experiences; that is, "consciousness" in the ordinary sense of the term. (2) The *Vorbewusste*, comprising the mental elements which, although not actually in consciousness at the moment, can be recalled at any time by the usual processes of association—*e.g.*, memories of past experiences, acquired knowledge, &c. (3) The *Unbewusste* (unconscious). The mental elements contained in the unconscious are prevented from entering into consciousness by the repressive force exerted by the "censure." They may nevertheless undergo a considerable development, and Freud maintains that complicated processes of thought may take place in the unconscious, of whose existence the individual himself is, of course, entirely ignorant. His theory bears a superficial resemblance to that of Hartmann, but differs from the latter in many fundamental respects.

Although a repressed complex is prevented by the censure from manifesting itself to consciousness in its normal manner, it nevertheless preserves an autonomous existence in the unconscious, and remains capable of influencing consciousness; but its influence is now distorted and indirect. For example, in certain elderly unmarried women the sex-complexes are subject to a considerable degree of repression, but manifest themselves symbolically in the guise of an exaggerated interest in births, marriages, and scandals [160].

To understand the mechanism by which these indirect expressions of a repressed complex take place, it will be necessary to consider some further aspects of Freud's theoretical teaching. He holds that the "affective" elements of the complex, in which he includes both emotional and conative factors, can be divorced from the ideas to which they properly belong and directed into other channels. In other words, the "affect" (*Affektbetrag*), corresponding to the "complex-energy" described in Section IV., is a separable quantity which may be "released from the idea to which it was primarily attached, thus entering into new psychical systems. This displacement of affect from one idea to another Freud denotes as transference (*Uebertragung*), and says that the second idea may in a sense be termed a representative of the first. A simple illustration of the process is when a girl transfers the affective process properly belonging to the idea of a baby to that of a doll . . . . treating it in all possible respects as she would a baby. An equally familiar observation is the behaviour of a spinster towards a pet animal" [139].

We are now in a position to continue our discussion of the various phenomena characteristic of the activity of a repressed complex. It has been explained that as soon as repression occurs the complex is unable to manifest itself to consciousness along the ordinary paths on account of the resistance offered by the censure. The essential ideas composing the complex are thereby compelled to remain unconscious, but their accompanying "Affektbetrag" (affective elements of the complex) may become separated in the manner described, and be linked with some other mental process which is not subjected to repression. The censure is thus, as it were, eluded, and the complex-energy is enabled to find an outlet, although in an imperfect and indirect manner. Thus in the case of Lucy R., described by Freud in 1895 [38], the patient was constantly troubled by a subjective sensation of smell resembling that of burning pastry. Analysis revealed that two months previously an event had occurred connected with a complex of great emotional force. At the moment when the episode took place it happened that some pastry which was being cooked in the room became burnt. The complex in question was subsequently—after a severe mental conflict—repressed, and apparently disappeared from the patient's mind. It manifested its continued existence, however, by the constant presence in consciousness of an element only connected with the real traumatic ideas by a chance contiguity—the smell sensation. That is to say, the complex energy became detached from its proper ideas, and linked itself with an indifferent mental element, which could express itself without opposition on the part of the censure.

The particular mode in which the repressed complex manifests itself varies in the different forms of psychoneurosis. Thus the "Affektbetrag" (affective elements of the complex) properly belonging to a repressed idea may become attached to some harmless conscious idea; the latter then becomes overweighted, and an obsession results. Or the energy of the complex may discharge into a somatic channel, leading to the production of some physical symptom. This is the characteristic mechanism of hysteria, and to it the phenomena of anæsthesia, paralysis, contracture, convulsions, &c., are to be ascribed. Hysteria is therefore differentiated from the other allied psychoneuroses by a tendency to expression by a somatic symptom. This diversion of the complex-energy into a physical channel is termed by Freud "conversion."

VII.—MECHANISM OF THE SYMPTOMS OF HYSTERIA.

The symptoms of hysteria thus arise as the final result of the following sequence of events: The simultaneous existence in the mind of two or more complexes which mutually inhibit each other leads to a state of conflict. The conflict, with its accompaniment of unpleasant emotional tension, is avoided by the process of repression. One of the complexes is repressed and becomes unconscious. It succeeds, however, in eluding the censure by various indirect methods. The phenomena which thereby result constitute the symptoms of hysteria.

It is only in his more recent writings that Freud adopts Jung's term "complex." Generally he expresses the corresponding ideas by the word "wish" (*Wunsch*),[1] and the facts we have just considered would appear in his own terminology thus: When a wish exists in the mind which is incompatible with the remainder of the personality, a state of conflict arises. Under these circumstances the wish may be repressed into the unconscious, and be cut off from participation in the normal mental processes. But " in the unconscious the repressed wish still exists, only waiting for its chance to become active, and finally succeeds in sending into consciousness, instead of the repressed idea, a disguised and unrecognizable surrogate-creation (*Ersatzbildung*). . . ." [95]. The hysterical symptom is, therefore, a mode in which the repressed wish can obtain gratification, although in a distorted and imperfect form.

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[1] Freud's use of the word "wish" cannot be regarded as altogether free from objection. The term tends to convey the notion of a definitely realized end, which the mind deliberately

The mechanisms by which the repressed wishes produce the hysterical symptoms are of various kinds. They are all, however, to be regarded as methods by which the resistance of the censure may be evaded. That is to say, they all serve the purpose of so distorting the original wish that its manifestation in consciousness is unrecognized by the personality. By this means the wish is partially gratified, but the former conflict between the opposing conative trends is avoided.

The most important of these mechanisms are: (*a*) *Symbolization.*—The symptom may bear a symbolical relation to the repressed wish—that is, it may represent the fulfilment of the wish in a symbolic, and therefore concealed, form. (*b*) *Condensation* (*Verdichtung*).—An individual symptom may represent two or more independent unconscious wishes, or elements thereof. The symptom is then said to be "over-determined" (*mehrfache Determinierung*), and its causal mechanism cannot be completely understood until all these independent unconscious elements have been laid bare. (*c*) *Displacement* (*Verschiebung*).—The affect properly belonging to a certain significant constituent of the complex is attached to some other mental element which is not under the ban of the censure. The latter element thereby assumes in the hysterical symptom an altogether disproportionate importance. This mechanism is illustrated by the case of Lucy R., described in Section VI. (*d*) *Representation of Opposite.*—Certain elements of the symptom may portray the exact opposite of the corresponding elements present in the unconscious wish. For example, the attitude assumed in an hysterical attack may be precisely the reverse of that implied

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strives to achieve. The theoretical considerations which Freud develops in the final chapter of *Traumdeutung* [70], however, indicate that he means to imply rather the progression towards an end, with or without a definite consciousness of that end, which is connoted by the English word "conation." It would appear, therefore, that the psychological fact in question would be better described by the term " conative trend."

in the repressed wish. (*e*) *Alteration in Time Sequence.*—The sequence of events which would occur if the unconscious wish were actually fulfilled may be reversed or otherwise distorted in the hysterical attack. For example, the commencement of the latter may represent the end-state of the wish-fulfilment.

All these mechanisms may be simultaneously exemplified in a single symptom, so that the determination of its exact significance may be a matter of extreme complexity and difficulty.

VIII.—DREAMS.

In his volume upon "Traumdeutung" [70] Freud brings the phenomena of dreams into relation with the general structure of his psychology.

Dreams are to be regarded as the expression, generally in a distorted form, of complexes which are subject to a more or less degree of repression. During the waking state the censure is sufficiently strong to prevent these complexes effecting an entry into consciousness, but during sleep the resistance is so weakened that they are enabled to manifest themselves. The censure, however, preserves sufficient power to ensure that the complexes can only make their appearance in a distorted and symbolic form. Dreams are not therefore, haphazard and meaningless productions, but indirect expressions of mental processes which are perfectly coherent and intelligible. These processes themselves are *unconscious*, and can only be reached by the employment of a special technique. Freud gives the name of "manifest content" to that aspect of the dream which is apparent to consciousness, while the underlying unconscious mental processes are termed the "latent content."

It will at once be observed that dreams are similar in their essential nature to the symptoms of the psychoneuroses. They provide, in fact, another means by which a repressed wish may evade the resistance offered by the censure. Moreover, the mechanisms by which the latent content is distorted into the manifest content are identical with those which we have already described in the psychoneuroses, condensation, symbolization, &c. It is owing to the effect of these mechanisms that the manifest content of a dream is so frequently bizarre and apparently senseless.

Starting from the manifest content, it is possible to discover the underlying latent content by the process of "psycho-analysis," a method of investigation which will be described subsequently. Dreams, therefore, offer a ready means of ascertaining the nature of the repressed complexes present in a given patient. Freud himself remarks that "Interpretation of dreams is, in fact, the *via regia* to the interpretation of the unconscious" [95]. The analysis of dreams is for this reason frequently employed as a method of unearthing the pathogenic mental processes underlying the symptoms of hysteria.

IX.—PSYCHO-ANALYSIS.

The method of "psycho-analysis" may be said to be the essential core of Freud's psychology. Upon it are based, not only the various mechanisms so far described, but also the sex-theories which form such an important part of Freud's later work, and the whole system of therapeutics which he claims to have established.

The aim of psycho-analysis is the determination of the repressed mental processes responsible for the symptoms of the various psycho-neuroses, and for other phenomena of the normal and abnormal mind. It will be remembered that, owing to the operation of the censure, these processes are prevented from appearing in consciousness except in a distorted and unrecognizable form, and that therefore the patient is himself unaware of their real nature. Hence, in order to achieve its end, psycho-analysis must in some way circumvent, as it were, the censure.

Freud originally employed hypnotism for this purpose (the so-called "cathartic" method), because in the hypnotic state the resistance of the censure is generally greatly lowered. Later, however, he found this procedure to be inadequate and subject to various disadvantages; and he has now altogether abandoned it in favour of his modern method of psycho-analysis.

Psycho-analysis comprises two more or less independent operations, free-associating (*zwangsloses Assoziieren*), and the interpretation by the physician of the memories, &c., thereby attained (*Deutungsverfahren*): (*a*) *Free-associating.*—The patient is encouraged to unburden his mind freely to the physician. He is asked to concentrate his mind upon a given symptom or circumstance and to relate every idea or memory which occurs to him, but to make no attempt to direct or control the flow of his thoughts. It is necessary that he should adopt an entirely non-critical attitude, recording everything which passes through his mind, however trifling, unpleasant, or irrelevant this may seem to be. The adoption of a non-critical attitude lowers the resistance of the censure, and it is found that the ideas then produced are all conditioned, to a greater or less degree, by the pathogenic complexes. (*b*) *Interpretation by the physician.*—Various peculiarities in the character and mode of production of the images and memories described by the patient, in particular certain phenomena indicating that resistance is being exerted by the censure, enable the physician to estimate their significance, and to determine ultimately the exact nature of the underlying complex. As an example of the way in which the censure manifests itself during an analysis may be mentioned the stoppages (*Lücken*) observed in the train of ideas produced by free-associating. The patient states that his mind is a blank, and that nothing occurs to him. After some persuasion on the part of the physician, however, an idea is finally produced, but the patient brushes it aside as trivial, irrelevant, or absurd. The real ground of the former suppression of the idea is, of course, that it is connected with the pathogenic complex—the belittling of its importance is an expression of the resistance offered by the censure. The method of interpretation has now been developed by Freud into a complicated technique requiring years of study and practice before it can be efficiently employed. The scope of the present review does not permit of any detailed description of its nature.

It has been already stated that the method of psycho-analysis can be applied, not only to the unravelling of the symptoms of the psycho-neuroses, but also to the determination of the latent content of dreams. In this case each individual element of the dream is taken separately, and subjected to a process of free-associating. The underlying complexes are then ascertained by the method previously mentioned. The analysis of dreams is therefore of considerable assistance in the investigation of the psycho-neuroses, the results serving to supplement the direct psycho-analytic examination of the symptoms themselves.

X.—ASSOCIATION EXPERIMENTS.

Further help in the investigation of the psychoneuroses may be obtained by the use of association experiments, conducted according to the methods devised by Jung, of Zürich 149]. The technique of these experiments is simple. A list of words is prepared, generally a hundred in number. These are called out by the experimenter one at a time, and the subject is required to react with the first word that occurs to him. The interval elapsing between the stimulus and the reaction is measured by a stop-watch. When the end of the list has been reached the experiment is repeated.

From the results thus obtained a trained observer can deduce conclusions of great value. These are based partly upon the general type of action displayed, partly upon the effects produced by individual stimulus-words. Jung found that if the stimulus-word aroused ideas connected with a complex of strong emotional tone, then the reaction obtained showed one or more of the following characters: Increase of the reaction-time, various peculiarities in the reaction-word, distortion of subsequent reactions, and failure to reply with the same word on repetition of the experiment. Whenever, therefore, these effects were observed, Jung concluded that a complex of some emotional force had been roused to activity. The precise nature of the complex could, moreover, often be conjectured from a comparison of the stimulus-word with the reaction produced.

The following example illustrates some of these points [169]:—

Stimulus-word	*Reaction-word*	*Reaction-time.*
(*a*) Head	Hair	1·4
(*b*) Green	Meadow	1·6
(*c*) *Water*	*Deep*	*5·0*
(*d*) Stick	Knife	1·6
(*e*) Long	Table	1·2
(*f*) *Ship*	*Sink*	*3·4*
(*g*) Ask	Answer	1·6
(*h*) Wool	Knit	1·6
(*i*) Spiteful	Friendly	1·4
(*j*) *Lake*	*Water*	*4·0*
(*k*) Sick	Well	1·8
(*l*) Ink	Black	1·2
(*m*) *Swim*	*Can swim*	*3·8*

The patient from whom this series was obtained had, during a recent attack of depression, determined to commit suicide by drowning. This complex has manifested itself in the associations which are italicized; (*c*), (*f*), (*j*), (*m*) are instances of increased reaction-time; (*m*) shows also a peculiarity in the reaction-word.

As a result of his researches Jung maintained that by means of the association experiment it was possible to obtain information concerning the principal complexes in the mind of a given subject. It was found, moreover, that similar effects upon the association experiment were manifested, even when the "constellating" complex existed in a state of repression. Hence it was obvious that the association experiment offered an additional means for determining the nature of the pathogenic complexes underlying the symptoms of the psychoneuroses. This method is, as a matter of fact, now generally adopted by Freud's followers as a preliminary to a detailed psycho-analysis.

XI.—The Sex Theories.

We have seen that the genesis of hysterical symptoms is attributable to the presence of unconscious complexes existing in a state of repression. So far, however, the precise nature of the complexes repressed has not been taken into consideration. Freud states that the results of psycho-analysis show that these are invariably of a sexual character, and that every case of hysteria owes its origin to the repression of sexual material. He considers, moreover, that the mode in which the sex-impulses develop in early life, forming the "sexual constitution," determines whether or not the individual is subsequently liable to the outbreak of a neurosis. In other words, he replaces the vague conception of a constitutional predisposition to the disease by precise factors capable of definite enumeration and analysis.

It should be prefaced that Freud uses the term "sexuality" in a sense far wider than that in which it is generally understood. Its connotation and denotation are, in fact, so extended that it is difficult to find any definition which will satisfactorily cover them. Sexuality, for Freud, includes everything bearing a direct or indirect relation to the sex-impulses and feelings—every psychical manifestation which ultimate analysis shows to be a derivative of the sexual instinct. Thus the term is applied to emotions like shame, to the affection of parents for children, and of children for parents, to the various manifestations of the sexual perversions, &c. Freud holds, also, that the sex-instinct makes its appearance in infancy, although its manifestations at that period are very different from those occurring in adult life. He claims that this extension of meaning is justified by the clear and coherent conception of the connexion between normal sexual life, perversions, and neuroses which is thereby attained. The unusually wide sense in which "sexuality" is employed by Freud must be carefully kept in mind whenever his sex theories are under consideration.

Freud's theories concerning the development of the sex-impulses, and their etiological significance in the genesis of the perversions and neuroses, are contained in the *Drei Abhandlungen zur Sexualtheorie* [75]. They may be shortly summarized as follow: Freud holds that the mental processes commonly called sexual, which bear a relatively precise relation to reproduction, are the outcome of a development from a broader group of processes in earlier life, of which certain ones have become selected and intensified while others have become suppressed. In the child are a number of sexual dispositions, the functioning of which notably differs from that of adult sexual processes, and the later development of which is subject to the greatest variability [139].

In the operation of the sex-impulses one may distinguish between the "sexual object" (*Sexualobjekt*), the source of attraction, and the "sexual aim" (*Sexualziel*), the action in which the impulse finds its satisfaction. The psycho-sexual manifestations occurring in the child take place in connexion with certain definite areas of the body surface, of which the most important are the external genitals, the anal region, and the mouth. Stimulation of any of these areas arouses specific feelings of pleasure, and they are therefore termed "erogenous zones." The sexual impulses of the child have at first no relation to a second individual, but find their satisfaction in the auto-excitation of the erogenous zones existing on the child's own body. In other words, the child is its own sexual object, and is therefore said to be "auto-erotic." Later, however, the impulses demand an external object, and their choice falls primarily upon the parents, predominantly upon the parent of the opposite sex, but to some extent upon both. It will thus be seen that at this stage the desires of the child contain a definitely homo-sexual component. Moreover, as all the erogenous zones may function independently, the child contains within itself the germs of the various perversions, and may hence be termed "polymorph perverse."

The sexual constitution of the adult results from a rearrangement of the factors present during child life, a process dependent partly upon congenital tendencies, partly upon the influence of environment and education. According to the manner in which this development proceeds the individual becomes normal, perverted, or neurotic.

In the process of normal development the genital zone proper acquires a dominating significance, while the remaining erogenous zones are relegated to a subordinate position. Certain of the impulses connected with the latter preserve an erotic significance, but serve simply to prepare and promote the normal sexual act. This applies, for example, to the subsequent development of the mouth zone (kissing), and to the impulses to see and touch the sexual object. Other impulses—*e.g.*, those relating to the anal zone—are subjected to a strong suppression by the opposing forces exerted by education and the environment, forces which manifest themselves as shame, disgust, &c. Education and environment ensure likewise that the homo-sexual components of the child's primitive impulses become efficiently suppressed, while the hetero-sexual become more sharply defined. The energy belonging to the various elements of the sex-impulses which have undergone suppression is diverted into other non-sexual channels, and becomes transformed into activities of a socially useful character. To this process of "sublimation" (*Sublimierung*) we owe those higher manifestations of the human mind which it is the aim of education to develop.

The rearrangement and development of the primitive sex-impulses take place during the "sexual latent period" (between about five and ten years of age) preceding puberty. When, therefore, the "high tide of sexual desire" comes with the advent of puberty, the paths along which it shall travel are already determined. If development has proceeded in the manner described above, these paths lead to a normal sexual activity subserving the reproduction of the species.

Should, however, the processes of development and adjustment have failed at any point, a perversion or neurosis results. If, instead of the genital zone proper acquiring its due significance, some other erogenous zone has been overdeveloped, then a form of perversion or fetichism will be produced. Similarly, if those partial impulses which normally serve to prepare and promote the sexual act are over-developed and become ends in themselves, such perversions as exhibitionism, &c., result. If, again, the homo-sexual component of the primitive sex-impulses fails to undergo suppression and sublimation, a state of partial or complete sexual inversion is produced.

The neuroses, on the other hand, depend upon an erroneous development in which the principal *rôle* is played by the process of "repression." In this case those components of the primitive sex-impulses which are normally discarded and sublimated into other forms of activity are repressed instead. It will be remembered that the effect of repression is that the impulses in question are cut off from the conscious life of the individual, but preserve an autonomous existence in the unconscious. So long as the state of repression exists these impulses cannot be sublimated into more useful activities, but continue to manifest themselves in the distorted forms already described.

In the hysterical, therefore, we find all those homo-sexual and other perversion components which exist in the undeveloped sexual constitution of the child, but now present in a state of repression. This has been aptly expressed by the phrase, "Hysteria is the negative of the perversions." It will be observed that the essential basis of the neurosis is thus the preservation of an infantile form of sexuality, and the failure of the latter to develop into the normal adult type.

The outbreak of the neurosis is generally due to the great increase in sexual desire which occurs at the time of puberty. The conflict between the normal outlet, the abnormal outlet, and the repressing forces exerted by education and environment thus becomes accentuated. The hysterical symptom is then produced as a compromise between the opposing trends, by which each attains a partial gratification. The mechanism of this process has been described in Section VII. Freud, therefore, maintains that every hysterical symptom is based ultimately upon a repressed component of the sexual impulses. Owing to the possibility of "over-determination" (*vide* Section VII.), the symptom can also serve for the expression of other repressed complexes, not necessarily of a sexual content, but the essential sexual component must always be present.

XII.—THERAPEUTICS.

The method of psycho-analysis is to be regarded, not only as a means of investigation, but also a necessary preliminary to the carrying out of curative measures. If the symptoms of hysteria are due to the operation of repressed complexes, then the first stage in a rational therapeutics must be the determination of the particular complexes present in each individual patient. At the same time the condition of repression must be done away with—that is to say, the complex must be removed from the unconscious, and again brought into a normal relation with the personality of the individual. If the repression can be satisfactorily abolished the morbid manifestations of the complex will *ipso facto* disappear, but the original conflict, evaded by the development of the psycho-neurosis, will inevitably reappear. In the full light of the facts obtained by psycho-analysis, however, more satisfactory methods of resolving the conflict become possible, in which repressions and neurotic symptoms can be altogether avoided. "Either the personality of the patient may be convinced that he has been wrong in rejecting the pathogenic wish, and he may be made to accept it either wholly or in part; or this wish may itself be directed to a higher goal which is free from objection, by what is called sublimation; or the rejection may be recognized as rightly motivated, and the automatic and therefore insufficient mechanism of repression be reinforced by the higher, more characteristically human mental faculties: one succeeds in mastering his wishes by conscious thought" [95]. The therapeutic method employed after a psycho-analysis may, in fact, be regarded as a process of re-education.

XIII.—Extensions of Freud's Psychology.

Freud's methods of investigation have been carried by himself and his followers into fields lying altogether outside the domain with which this review is mainly concerned. The various departments of the subject are so closely interconnected, however, that no adequate understanding of Freud's psychology is possible without some knowledge of the extensions in question. The works dealing with them have therefore been included in the bibliography attached to the review.

Freud separates from hysteria the anxiety (*Angst*) and compulsion-(*Zwang*) neuroses. Their mechanism, however, resembles in many essential respects that of hysteria. As in the latter, unconscious repressed complexes play the chief *rôle*, but their mode of manifestation is different. The consideration of these neuroses cannot be entered upon here—the reader is referred to the various works on the subject mentioned in the bibliography. Freud's latest views on the compulsion-neuroses are contained in his "Bemerkungen über ein Fall von Zwangsneurose" [93].

Among the other extensions of Freud's work may be mentioned his analysis of the phenomena of wit [77], his numerous articles dealing with the psycho-pathology of everyday life, and his investigation of certain symptoms occurring in a case of paranoid insanity. This latter investigation formed the starting point for a line of research which has undergone great development in the hands of Bleuler, Jung, and their followers. In particular, the work of Jung upon dementia præcox [160] constitutes one of the landmarks of modern psychiatry.

Freud's adherents have also carried his psychological methods into diverse fields which at first sight have no apparent connexion with the phenomena of the psychoneuroses. Mythology, folk-lore, sociology, pedagogy, art, &c., have been successively attacked. In all these extensions the keynote of research has been the endeavour to establish the wide-reaching importance of Freud's fundamental principles—the determination of mental processes by unconscious psychic factors, the existence of emotional conflicts, and the causation of various phenomena as a result of repression. It has been well remarked that "Freud's psychology signifies a great deal more than the formulation of a series of new conclusions or the announcement of new discoveries, important as these may be; it involves a radical change in our attitude towards the structure and functioning of the mind" [139].

XIV.—CRITICISMS.

Freud's theories and methods have met with a very mixed reception from the scientific world. During recent years his school has rapidly increased, both in numbers and importance, but a considerable opposition, including some of the most influential names in Europe, still exists.

Among the writers who accept Freud's doctrines more or less completely may be mentioned Abraham, Adler, Baroncini, L. Binswanger, Bleuler, Brill, Claparède, Ferenczi, O. Gross, Jones, Jung, Juliusburger, Maeder, Muthmann, Putnam, Rank, Riklin, Sadger, Stegmann, Seiner, Stekel, Strohmayer. The opponents, on the other hand, include Alt, Aschaffenburg, Foerster, Friedländer, Heilbronner, Hoche, Kraepelin, Moll, Oppenheim, Raimann, Schnitzler, Spielmayer, Storch, Ziehen.

Much of the hostile criticism which at first greeted Freud's work was due to an incomplete understanding of the principles involved or an unreasoned aversion to his methods of investigation. Freud's insistence upon the importance of the sex-factors was attacked from all sides, mainly upon ethical or æsthetic grounds. Criticism of this character may possibly have some force when the matter at issue is one of therapeutic method, but it is necessarily irrelevant when it is applied to the purely scientific question of the origin and nature of the psychoneuroses.

Latterly, however, the opposition to Freud's doctrines has assumed a different aspect. His methods have been considered in detail, and subjected to the ordinary canons of scientific criticism. The works of Isserlin [123-131] may be cited as exemplifying this attitude. He maintains that the method of psycho-analysis, the basis of all Freud's work, is open to grave objection as a mode of scientific investigation, and that therefore the results obtained by it cannot be regarded as established.

Many writers are prepared to accept certain of Freud's conclusions, but decline to identify themselves with his psychology as a whole. Thus Freud's general principles, the conceptions of conflict and repression, and many of his views on the mechanism of certain symptoms, are acquiring a rapidly increasing recognition. Most of the writers in question, however, adopt a sceptical attitude concerning the sex-theories, the "Deutungsverfahren" in the method of psycho-analysis, and various other points.

Among the authorities who adopt an intermediate position with regard to Freud are: Bezzola, Eulenburg, Forel, Frank, Hänel, Hellpach, Löwenfeld, L. W. Weber.

Freud's psychology has now reached a stage of development which calls imperatively for complete investigation and appraisement of its value. The whole subject must be submitted to searching and impartial criticism, the basic facts must be confirmed, and the justification of the deductions built upon them accurately estimated. Should it be found that the structure satisfies the requirements of science, then Freud's achievment must be reckoned among the most considerable in the history of human knowledge. If, however, errors, exaggerations, and hypotheses without adequate foundation are discovered, then it becomes the duty of science to separate the wheat from the chaff, to determine how much of Freud's psychology is worthy of preservation, and what are the lessons which may be profitably gained from it. For there is a growing consensus of opinion that Freud's works bear everywhere the impress of an extraordinarily acute and original intelligence, that his theories are at any rate remarkably suggestive and stimulating, and that he points the way to many lines of research which have never been previously attacked.

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PUBLICATIONS RECENTLY RECEIVED.

[Notes on a book under this heading do not preclude a subsequent review.]

A System of Medicine by many writers. Edited by Sir CLIFFORD ALLBUTT, K.C.B., and HUMPHRY DAVY ROLLESTON, M.D. Vol. VII, *Diseases of the Muscles, the Trophoneuroses, Diseases of the Nerves, Vertebral Column and Spinal Cord.* Pp. 900. Vol. VIII, *Diseases of the Brain and Mental Diseases.* Pp. 1070. London: Macmillan, 1910.

Volume VII.—Within the limits of a short notice it is impossible to mention the many admirable points in these two volumes. Every section has been carefully revised, and most have been entirely rewritten by authors, who have a first-hand knowledge of the disease in question. This gives to the contents of most of the chapters a clearness and precision absent from most text-books. Dr. Mott's remarkable "Introduction to Neuro-pathology" should be read by every student of nervous disease. Myasthenia gravis (Dr. F. Buzzard), Amyotonia congenita (Dr. Collier), the Myopathies (Dr. Batten), have been added to the account of muscular diseases. The section on diseases of the spinal nerves has been revised by Dr. Fleming, whilst Dr. Batten and Dr. Gordon Holmes have rewritten the account of the various forms of progressive muscular atrophy. Dr. Wilfred Harris contributes a new account of syphilis of the spinal cord and its membranes. Dr. Ormerod deals with tabes dorsalis, and Dr. Risien Russell has revised his article on "Disseminated Sclerosis." This volume bears witness to the vitality of neurology in this country, and should be in the hands of every practitioner and student who is interested in disease of the nervous system.

Volume VIII.—This volume is devoted to diseases of the brain and of the mind. Dr. Ferrier contributes a description of regional diagnosis in cerebral disease. Aphasia, apraxia, and agnosia are fully dealt with, and general paralysis of the insane is included amongst the gross diseases of the brain. The tics (Dr. Risien Russell) have been brought up to date, and the article on "Hysteria" has been rewritten by Dr. Ormerod. Sir Clifford Allbutt treats of "Neurasthenia," whilst amongst the shorter articles Dr. Guthrie's account of "Night Terrors and Allied States" is excellently written.

In the second half of this volume the insanities are classified for the most part into causal groups. This makes it impossible to treat fully of the many vexed questions of mental disease; thus the difficulties surrounding paranoia, dementia præcox, and maniacal depressive insanity are alluded to rather than discussed.

Beiträge zur Pathologie des Stoffwechsels bei Psychosen. Dritter Teil, Funktionelle Psychosen. Von Dr. MAX KAUFFMANN. S. 238. Jena: Fischer, 1910.

"Geisteskranke sind Gehirnkranke," and diseases of the brain influence metabolism; this might form the motto of this laborious work. The author believes that the cardinal symptom in the "Angstpsychosen," of Wernicke, is the change in respiration; transitory glycosuria may also occur. In katatonia the extreme want of movement is associated with a diminished oxidation and a retention of nitrogen. After considering many other metabolic questions in connexion with insanity, such as acidosis, the supposed occurrence of cholin, &c., he concludes that the human organism is not a test-tube and that the action of metabolic changes on the brain, and specially on the cortex, is a question of cerebral pathology, and not of pathological chemistry.

Untersuchungen über die Temperatur des Gehirns. Von Professor HANS BERGER. S. 130. Jena: Gustav Fischer, 1910.

These observations, to which the author was apparently stimulated by the well-known experiments of Mosso, which showed that variations in the temperature of the brain substance may be independent of that of the blood, were made on a chimpanzee and on eight human patients. In the human cases specially made thermometers were inserted in the brain after the skull had been perforated for the purpose of the localization of lesions, by Neisser and Pollack's Hirnpunktion method, and the readings were recorded simultaneously with those of a thermometer placed in the rectum. In five cases the observations were made while the patients were under general anæsthesia, and in two after they had recovered from the preliminary narcosis. A series of eight observations were made at intervals on the chimpanzee without anæsthesia. Berger's observations confirm Mossa's main conclusions, and he was also able to observe the influence of various factors, as mental effort and epileptiform fits, on the temperature of the brain.

Untersuchung der Pupille und der Irisbewegungen beim Menschen. Von KARL WEILER. S. 176, mit 43 Figuren im Text und 3 Tafeln. Berlin: Julius Springer, 1910.

This brochure is a reprint of a paper published in the *Zeitschrift für die gesamte Neurologie und Psychiatrie.* It contains a number of valuable observations made by the aid of complex apparatus devised by the author. He also recorded the movements of the iris by cinematograph.

The careful record and analysis of facts that the monograph contains should make it useful to those interested in the clinical aspect of the subject, but the pathology of the pupillary movements is not dealt with.

Die Paralysis agitans. Von KURT MENDEL. S. 106. Berlin: Karger, 1911.

This short monograph contains an excellent account of the symptoms of paralysis agitans and a large number of observations, many original, others collected from the literature, on its rarer features. The more important of the numerous contributions to its morbid anatomy and pathology are also reviewed; but, as the author admits, we know nothing definitely of either. Personally he inclines to the opinion that it is probably a diffuse cerebrospinal disease by which the motor tracts are chiefly affected. The section that deals with treatment is a valuable contribution to therapeutic experience.

Infantile Paralysis in Massachusetts in 1909. Reprinted from the *Monthly Bulletin of the Massachusetts State Board of Health,* for June, 1910. Pp. 105. Boston: Wright and Potter, 1910.

This pamphlet contains an analysis of the epidemic of poliomyelitis, which occurred in Massachusetts in the year 1909. One hundred and fifty cases were studied carefully. The largest number occurred in the month of August, and in children aged 2. One adult only was affected. Dr. Lucas gives an account of the condition of the blood and cerebrospinal fluid in the prodromal and early acute stage of the disease in four human cases, and in monkeys inoculated with material obtained from Dr. Flexner. The blood showed a lymphocytosis, whilst the increase in white cells in the cerebrospinal fluid consisted mainly of lymphocytes and the small mononuclear forms.

Neurasthenie. Eine Skizze. Von Dr. OTTO VERAGUTH. S. 156. Berlin: Springer, 1910.

We can heartily recommend this little book to those who are anxious to know the trend of modern ideas on "Neurasthenia." It is well arranged, and the opinions of the author are remarkably temperate. No modern theory is neglected; the views of Goldscheider, Janet, Freud and Dubois are considered in turn, but not polemically. The remarks on the various forms of treatment are excellent.

Die klinische Stellung der Angstpsychose. VON Dr. EDM. FORSTER. S. 260. Berlin: Karger, 1910.

Wernicke described a group of psychoses where fear was the main symptom, and from it all the other manifestations could be directly deduced. According to the author of this clinical study such a category is not justified. Where fear is a prominent feature of a psychosis it is a part only of the insane state which will, at one time or another, reveal itself as the condition underlying the fear. The book is written under the influence of the school of Ziehen, and is strongly opposed to that of Kraepelin.

Die psychische Krankenbehandlung in ihren wissenschaftlichen Grundlagen. VON BERTHOLD KERN. [Vortrag gehalten im Verein für innere Medizin in Berlin am 15 November, 1909.] S. 59. Berlin: Hirschwald, 1910.

This is a philosophical consideration of the relation of mind and body as an introduction to the psychical treatment of disease. Practical details do not enter into the scope of this address.

The Mental Symptoms of Brain Disease. By BERNARD HOLLANDER, M.D., with a preface by Dr. JULIUS MOREL. Pp. 237. London: Rebman, 1910.

The author has collected a large number of cases from medical literature, in which mental symptoms were associated with a lesion of the brain. He begins with the well-known changes produced by disease of the frontal lobes. He then attempts to show that lesions of the parietal convolutions produce "mental states of depression and melancholia," lesions of the temporal lobes, violence and destructiveness. The mental effects of occipital lesions are doubtful, excepting in as far as they may be due to loss of sight. Most of the cases are inadequately described, and in many instances lists alone are given of cases which the author considers support his view. The author's description of those instances in which operations were undertaken for the relief of such mental symptoms will satisfy no modern neurologist.

Writers of "Original Articles and Clinical Cases" are supplied free of charge with 50 copies reprinted in the form in which the paper stands in the pages of "Brain." If reprints are required in pamphlet form, with wrapper, title-page, &c., and re-numbered pages, they must be ordered, at the expense of the writers, from Messrs. BALE, SONS & DANIELSSON, Ltd., 83-91, Great Titchfield Street, London, W.

Members of the Neurological Section of the Royal Society of Medicine can obtain the Index of "Brain" for the Volumes I. to XXIII. inclusive, that is, from its commencement to the end of 1900, from Messrs. MACMILLAN & CO., Ltd., St. Martin's Street, London, W.C., at the price of 6s. 6d., post free.

To those who are not members of the Neurological Section of the Royal Society of Medicine the price is 8s. 6d. net, and the volume may be obtained through any bookseller.

EDITOR.

[MARCH, 1911.]

CALCUTTA UNIVERSITY LIBRARY

BRAIN.

PART IV., VOL. 33.

Original Articles and Clinical Cases.

ON THE RELATIONS BETWEEN CORRESPONDING POINTS OF THE TWO RETINÆ.

BY WILLIAM MACDOUGALL, M.B.

WHEN the normal man looks at any object, say, a candle, in the ordinary way, he perceives only one candle, although two optical images are thrown upon his optic apparatus, one upon each retina, and each initiates a nervous process which, on being transmitted to the brain, is capable of producing a perception of the candle hardly distinguishable from that induced by the duplicate processes of binocular vision. This fact of "single vision," in spite of the duplication of the nervous processes necessary for vision in all the peripheral parts of the optic apparatus, has commonly been explained by the assumption (made by Newton, Johannes Müller, and Aubert, among other authorities) of a common cerebral centre for each pair of corresponding points; that is to say, it is supposed that the fibres of the optic nerves which carry to the brain the excitations initiated in any two corresponding points of the two retinæ are connected in the brain with one organ (cell, path, or centre) in which the sensations are excited, so that when the two corresponding points of the retinæ are simultaneously stimulated this central organ is thrown into a state of excitation which is the common psychical resultant of the two independent peripheral excitations.

Of recent years it has been pointed out by several authors that many facts of binocular vision cannot be reconciled with this hypothesis of a common cerebral centre for corresponding points; yet it would seem that it is still widely held. For, although the problem of the conditions of single vision (as it may, for brevity's sake, be designated) is not touched upon by several of the most recent text-books on the senses, and though the doctrine of the common centre is repudiated or only vaguely and doubtfully suggested in others, this old assumption continues to appear in others; and it is necessarily implied by Hering's theory of the visual processes,[1] which still continues to find favour among a large number of physiologists and psychologists. It seems worth while, therefore, first to array the evidences which, as it seems to me, render this doctrine of a common centre wholly untenable; secondly, to indicate certain conclusions which must follow from its rejection; thirdly, to suggest a scheme of the anatomical and physiological relations of corresponding points which seems capable of accounting for most of the phenomena peculiar to binocular vision. The paper accordingly divides itself into three sections.

I.—*The Evidences of Separate Cerebral Paths for Corresponding Points.*

(1) Any illuminated surface appears no brighter (or but very slightly brighter) in binocular than in monocular vision; or, in other words, the simultaneously equal stimulation of corresponding points evokes a sensation of no greater (or of but very slightly greater) intensity than that evoked by similar stimulation of one of the points only.[2] Now, if corresponding points transmitted their excitations to a common centre, the excitement of that centre, and the resulting sensation, should be no less intense when two corresponding points simultaneously receive a stimulus of a given intensity than when one of them receives a physical stimulus of twice that intensity.

(2) Under certain conditions the stimulation of one of a pair of corresponding points not only adds nothing to the intensity of the sensation evoked by stimulation of its fellow, but actually diminishes it. This effect (generally known as Fechner's paradox) may most easily be observed by looking at any brightly illuminated surface with one eye only and, after a few seconds, opening the other eye behind a darkly smoked glass. At the moment of opening the second eye the surface seems to become very distinctly less bright. Yet, if the doctrine

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[1] The logical necessity of this implication is sufficiently obvious, but will be exhibited on a later page.

[2] Observers are not in agreement on this point. It is generally said that in binocular vision the sensation is very slightly more intense; but Sherrington [14] could discover no such superiority. The comparison is a strangely difficult one, but my own observations lead me to the conclusion that dimly illuminated surfaces appear appreciably brighter in binocular than in monocular vision, but that with brightly illuminated surfaces no such difference is perceptible.

of a common centre were true, the feeble stimulation of the one area should add something, however little, to the intensity of the excitation of the common centre due to the stronger stimulation of the corresponding area.

(3) If an after-image is formed in one eye, and allowed to die away while the eyes remain at rest and shielded from all light, it may generally be revived several or many times by momentarily allowing a diffused and faint light to reach the stimulated retina through the closed eyelid. The admission of a similar diffused stimulus to the other eye may produce under favourable conditions a similar effect, but its influence is in this case very much feebler [3].

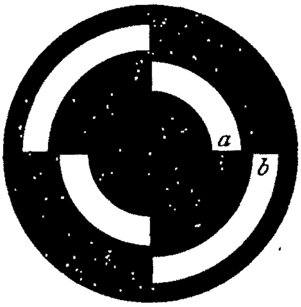

FIG. 1.

(4) On rapidly intermittent stimulation with light of given intensity, flicker-point (the rate of succession of stimuli which just suffices to extinguish flicker) is the same, or very nearly the same, whether the stimuli fall on one retina only (or simultaneously on both) or alternately on corresponding areas of the two retinæ (*i.e.*, are applied in such a way that, while the area of one retina is receiving the stimulus, its fellow receives no stimulus, but receives it in the succeeding moment, when the first is no longer under stimulation). Sherrington [14] has obtained this result by a very refined procedure, and I have confirmed it with a number of subjects by means of a very simple procedure. In a disc of mill-board windows are cut in the way indicated in fig. 1. The distance *a* to *b* is made equal to the interocular interval. The disc is set in rotation before an illuminated surface, and the subject looks at the surface through the disc, taking up a position such that one eye receives the rays from the surface through the outer pair of windows, the other through the inner pair. Flicker-point may then be conveniently determined by keeping the rate of rotation of the disc constant and varying

the illumination of the surface by moving the lamp nearer to, or further from, it. It is then found to be the same (or only very slightly different) whether both eyes are stimulated alternately or one is covered.

Now flicker, and the extinction of flicker, must be determined by processes in the cerebral centres (not improbably by the rate of succession of discharges of neurokyme across the synapses of the visual tract) [4]. If the corresponding points transmit their activities to a common centre, this centre must receive in a given time, when both eyes are stimulated at a given rate, but alternately, twice as many stimuli as when one eye alone is stimulated at the same rate. And if flicker is extinguished when the stimuli fall on one eye only at a given rate (say, thirty per second), then, when the two eyes are alternately stimulated, it should be extinguished by stimulation of each eye at half that rate (fifteen per second). But this, we see, is not the case; each eye requires to be stimulated thirty times per second.

(5) The following facts of binocular rivalry and fusion cannot be reconciled with the hypothesis of the common centre:—

(*a*) If two fields of slightly different texture and quality are combined binocularly, if, for example, one of them is marked by a slight flicker (Sherrington) [14], the observer is able to distinguish the peculiarities of the two fields by selective attention; and if the differences between them are made greater, one has no difficulty in directing the attention to the peculiarities of either field in turn. In the extremer instances of such differences (as when one uses a monocular microscope while keeping both eyes open) the one field may be wholly suppressed for consciousness; but every gradation between this total suppression of the one field and the full presence of both seems to be possible. (*b*) When two plain fields of different colour are projected upon corresponding areas of the two retinæ, one sees an alternation of the two colours with intervening periods of partial or complete fusion or blending of the effects of the two stimuli, which blending follows in the main the same rules as monocular colour mixture. This familiar fact of struggle or rivalry of the two colours is in itself difficult to reconcile with the hypothesis of a common centre; but a much greater difficulty is presented by the facts (*c*) that if the intrinsic muscles of one eye are paralysed with atropine during the experiment, an effort of accommodation causes the predominance of the colour presented to the unparalysed eye [5]; (*d*) that by a voluntary effort one can favour the predominance of either colour at will, even though the intrinsic muscles are paralysed [5].

(6) If one eye fixes for a few seconds or more a variegated field which moves constantly in one direction and is then directed upon a stationary surface, this appears for some little time to flow in the direction opposite to that of the former field. If, while one eye fixes the moving field, the direction of the motion is reversed every few seconds, and then after some minutes of such fixation the motion is maintained in one direction for a longer period, the illusory reversed motion is very much diminished in vividness and duration; it would seem that the physiological mechanism on which the illusory "after-image" of motion depends is fatigued by the prolonged stimulation of alternating direction. But the production of the after-image of motion in the other eye is not appreciably affected. This fact implies that the mechanism on which the "after-image of motion" depends exists in duplicate, one for each eye.[1]

(7) If "single vision" depended upon a conjunction of the central paths of corresponding points, we ought to find single vision strictly confined to corresponding points. But it is a well-known fact that disparate points may also subserve single vision so long as their disparation is small. Every stereoscopic combination involves such single vision with disparate points, and the stereoscopic effect is dependent upon it. Moreover, the degree of disparation compatible with single vision varies under practice and with slight changes of conditions, so that disparate images may be at one moment fused and at the next may fall apart and be seen as double images.

(8) It seems to have been fully established that in certain cases of squint, binocular vision involving fusion of widely disparate images exists, an abnormal system of correspondence having been acquired through use. And it seems to have been established also that in some of these cases, after the cure of the squint by surgical operation, the patient sees for some time double images, although the optical retinal images fall upon the normally corresponding points; and that these gradually give place to normal binocular vision, the normal system of correspondence becoming established by use and the abnormal system being broken up [1], [12]. This variability of the correspondence with practice is clearly difficult, if not impossible, to reconcile with the hypothesis of a common sensory centre for corresponding points.

(9) Perhaps the strongest evidence against the "common centre"

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[1] These facts have been observed by Mr. A. Wohlgemuth, and are reported in a paper shortly to be published in the *British Journal of Psychology*. I have to thank Mr. Wohlgemuth for his permission to mention them here.

is afforded by the facts of functional blindness of one eye, whether occurring as a symptom of hysteria or induced by hypnotic suggestion. We seem compelled to believed that in such cases the sensory centre of the blind eye becomes functionally dissociated from the rest of the cerebrum or thrown into a state of paralysis (perhaps through a raising of its internal resistances), while that of the other eye continues to function normally; and both suppositions are incompatible with the hypothesis of a "common centre."

(10) The hypothesis of a "common centre" is supported by no evidence, except what slight presumption in its favour is afforded by the facts that the fibres carrying up impulses from corresponding points go to the occipital cortex of the same hemisphere, and that their centres or paths within that cortex lie so near together that when a lesion of this part of the cortex destroys the paths from one retina, the paths from the corresponding points of the other seldom escape injury. But it would seem that in some cases they do escape. Cases of hemianopia due to lesion of the occipital cortex on one side have been reported, in which, while the hemianopia was complete for one eye, small areas of the corresponding half of the other retina have retained their functions partially or completely [13]. It is clear that if these instances may be accepted as well established, they suffice to refute the doctrine of the "common centre."

(11) It seems that the owl, the frog, the chameleon, and other beasts of prey enjoy binocular vision in spite of the fact that in them the decussation of the fibres of the optic nerves at the chiasma is complete [14].

(12) Finally, the hypothesis of the "common centre" is founded upon a radical misconception of the conditions of fusion of effects of sensory stimuli. This misconception is that the sensation evoked by the stimulation of any sensory point or nerve-fibre comes into existence as an isolated or detached fragment of psychical existence, and that such fragments become compounded to form a consciousness only in so far as there obtains some special ground or cause of such compounding in the form of a corresponding fusion of the nervous conditions of the several sensations. To make this assumption is to invert the true statement, which may be formulated in the following way. In so far as sensory stimuli affect consciousness, they produce partial modifications of the complex but unitary whole of consciousness; and, when several stimuli simultaneously affect consciousness, their effects in consciousness can only be discriminated or distinguished from one another in so far as there obtains some special ground of distinction. Such special

grounds are of two principal classes—namely, differences of quality and differences of local signature of the several sensory effects or sensations, as we commonly call them; and the power of distinguishing or holding apart sensation-elements by aid of either of these grounds of distinction depends largely upon previous practice in active discrimination. The truth of these statements may be best brought home to us by reflection upon those sensory experiences in which the influence of local signature is at a minimum or absent. Thus we see clearly that in the province of auditory experience the discrimination of the sensation-elements that enter into a musical clang depends upon differences of their quality and upon previous practice and training in the discrimination of similar qualities. To the average untrained ear the tones of a clang are fused or confused in one whole; but the discrimination may be facilitated by differences of local signature. In a similar way odours and tastes blend or fuse with a degree of intimacy inversely proportional to their distinctness of quality.

When, therefore, we find sensations of similar quality fused in a manner that resists analysis (or, to speak more strictly, where stimuli, which evoke similar sensation-qualities when successively applied, are applied simultaneously, and conjointly produce a change in the sensory content of consciousness in which the effects of the two stimuli cannot be distinguished in any way from one another), we have not to seek any special physiological ground of this fusion of their effects to a common resultant, such as a fusion of the two sensory nerve-processes in some common centre; for such a fusion of effects in consciousness is the fundamental law of sensory processes. But, rather, when simultaneous stimuli evoke sensations of similar quality which nevertheless are distinguishable, then we have to seek some special ground for the possibility of this discrimination. It was by considerations such as these that Lotze was led to propound his celebrated doctrine of local signs.

If, now, we apply these considerations to the cases of the results of simultaneously stimulating pairs of corresponding and of disparate points, we see that the fact for the explanation of which some physiological ground must be sought is, not the fusion of effects of stimuli applied to corresponding points, but rather the fact that stimuli of similar quality applied to any other two points (whether of one retina or in the two retinæ respectively) produce effects in consciousness that are distinguishable. For corresponding points are points that have identical local signature; the spatial meanings attaching to their sensational effects are identical, and therefore there is no ground for their distinction, no possibility of holding them apart in consciousness. And if we further ask, Why is their local signature identical? the best answer we can find seems to be—because the paths proceeding from any pair of corresponding points terminate in a common final path on the motor or efferent side; or, in other words, because the stimuli applied to any pair of corresponding points evoke the same motor tendency.

The facts and considerations stated in the foregoing pages seem to me to warrant the confident rejection of the hypothesis of a common sensory centre for corresponding retinal points and the assertion that the cerebral processes through which the stimuli applied to corresponding points produce their effects in consciousness take place in parts of the brain anatomically separate and distinct.

In another publication I propose to develop at length certain important implications of this conclusion [6], bearing upon the doctrine of psycho-physical parallelism, and here I wish only to insist upon its bearing upon the theories of the visual processes.

II.—*The Bearing of the Conclusion established in Section I on Theories of the Visual Processes.*

The conclusion is strongly favourable to the Young-Helmholtz theory, and wholly incompatible with Hering's theory of the visual processes. The most fundamental difference between the two theories is that expressed by the designation of the theories as those of the "component" and "opponent" processes respectively. The component theory, as usually understood and as formulated by Young and Helmholtz, implies that the composition of effects of visual stimuli exists only in the psychical sphere, only for consciousness; that, for example, when complementary rays stimulate the same part of one retina, or corresponding areas of the two retinæ respectively, the resulting achromatic sensation is the common effect or resultant in consciousness of three physico-chemical processes occurring in three separate and distinct groups of cerebral elements of specific constitution, which subserve the three primary qualities of visual sensation, red, green, and blue respectively.

Hering's theory of opponent processes, on the other hand, assumes that all the constituents of the mixed ray falling upon an area of one retina, or the two "complementary" rays falling upon corresponding areas of the two retinæ and exciting achromatic sensation, act upon the same "visual substance" and produce in it a physico-chemical process which is the complex resultant of the several stimuli. Now the demonstration that "corresponding points" do not propagate their excitations to any common centre is at the same time a demonstration that no such complex physico-chemical resultant of the complementary stimuli as is assumed by the "opponent" theory can be formed when they fall upon corresponding areas; or, in other words, it follows that the effect in consciousness of stimulating corresponding areas with complementary rays (namely, achromatic sensation) is the common resultant of separate and distinct cerebral processes initiated in the two retinæ, and running their courses in anatomically distinct cerebral elements. And, if this is true in the case of achromatic sensation excited by complementary stimuli falling upon corresponding points, it is in the highest degree probable that it is true also of the achromatic sensation excited by complementary stimuli falling upon an area of one retina; for it can hardly be supposed that binocular colour mixture depends upon conditions radically different from those of monocular colour mixture.

If, then, the separateness of the cerebral paths or centres of corresponding points is established by the evidences reviewed above, it follows that the fundamental conceptions of Hering's theory of opponent visual processes are untenable.

These plain implications of the facts of binocular vision have been so completely overlooked, and my brief indication of them in a former publication [3] has been so completely ignored, that it seems worth while to present the argument in another and simpler fashion—namely, in relation to the problem of the nature of the yellow quality of sensation.

A necessary feature of the "opponent theory" is the view that yellow is a simple quality of sensation dependent upon (or correlated with) a cerebral process of one specific kind; whereas the "component theory" regards yellow as the psychical resultant of two simultaneously occurring cerebral processes which, when they occur successively, evoke sensations of red and green qualities respectively. And the alleged psychological simplicity of yellow (i.e., the impossibility of discovering in it unmistakable affinities to red and green, similar to the affinities to both red and blue that we discover in purple) is commonly claimed as one of the chief superiorities of the "opponent theory." Now, when corresponding areas are simultaneously stimulated with "red" and "green" rays respectively, the effect in consciousness is (except during periods of rivalry or alternation of red and green) the yellow quality. But it has been proved that the corresponding points have no "common centre"; hence the yellow quality resulting from the binocular combination of red and green (or, more strictly, from the simultaneous stimulation of corresponding points with red and green rays respectively) is a psychical resultant of two separate cerebral processes, or, in the common phraseology, is a compound quality of sensation. Hence the proof of the separateness of the cerebral centres of corresponding points is fatal to Hering's theory of opponent visual processes, and is in harmony with, and strongly supports, the fundamental assumptions of, the component theory.

III.—*The Anatomical and Physiological Relations of Corresponding Points.*

It is, I think, possible to suggest a comparatively simple view of the anatomical and physiological relations of corresponding points which shall be in harmony with all the facts of binocular vision and will afford explanations of many of them.

I begin by accepting the essentials of Lotze's theory of local signature of the visual sensations as originally propounded by him—namely, the view that the local signature of the visual sensation excited by stimulation of any retinal point is bound up with, or is a function of, the motor tendency excited by stimulation of that point; and that all points of the retinæ stimulation of which evokes identical motor tendencies yield sensory effects of identical local signature. For my present purpose it is not necessary to enter into the obscure problem, How exactly does the motor tendency subserve local signature?

Now, corresponding points have identical motor tendencies, so far at least as concerns turning movements of the head and eyes (with the partial exception of movements of convergence of the eye-balls); and on this and other grounds we find good warrant for the assumption that the cerebral paths of any pair of corresponding points, although they remain separate throughout that part of them in which the qualities of sensation are determined, nevertheless converge in their distal or efferent parts upon a common motor path, the conjunction probably taking place in the subcortical region.

The identity of motor tendency thus secured to corresponding points is the ground of singleness of binocular vision, or, in stricter language, the absence of any sufficient difference of the motor tendencies evoked by stimuli applied to two corresponding points renders the sensory effects of such stimuli spatially indistinguishable.

If now we add to this well-founded assumption that the paths of corresponding points issue in a common final path on the motor side, a second assumption, we have a sufficient anatomico-physiological scheme for the explanation of the facts of binocular vision. This second assumption is that the cerebral path from every point of either retina is connected either directly or indirectly with the path from every other point of the same retina in the manner that determines reciprocal inhibition, and that the paths of corresponding points are connected in the same way, that the relation of reciprocal inhibition obtains between them also. In my papers on the theory of the visual processes [3] I have shown how all the facts of light and colour contrast, as well as others, are adequately explained by the hypothesis that the relation of reciprocal inhibition obtains between all chains of retino-cerebral elements and is especially intimate between the members of each set of such elements subserving one of the primary qualities of visual sensation; and in my notes on smoothly graded contrast [7 and 8] I have described a peculiarly intense form of contrast which is well explained by the hypothesis of inhibition by drainage set out in another paper [9], but which presents great difficulties for any other theory of nervous inhibition. My present suggestion is, then, that the cerebral paths of corresponding points are connected together in their afferent parts in the way that all the paths from points of one retina are connected with one another—namely, in the way that renders possible reciprocal inhibition by drainage—as well as by convergence to a final common path at their efferent ends. This scheme seems to me to account for the facts more adequately than one briefly indicated in a note published some years ago [10].

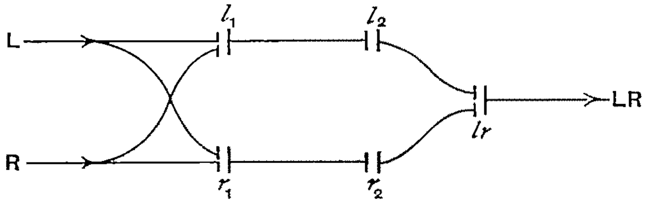

FIG. 2.

The scheme may be represented diagrammatically in the simplest possible manner by fig. 2. In this diagram the paths right and left from two corresponding points must be regarded as existing in triplicate at least in their middle or cortical parts; the three parallel chains of retino-cerebral elements of each triplicate path containing elements of three specific constitutions that subserve the three primary qualities of colour sensation, red, green, and blue respectively. And the relation of reciprocal inhibition, indicated in the diagram by the lines crossing over from R to L and from L to R, must be supposed to hold between all the chains of elements.

The middle parts of the lines L and R are meant to represent the cortical parts of the sensory paths; it is probable that their afferent parts are connected more directly with the final common path L R in the subcortical level as well as by the cortical paths, but it seems unnecessary and undesirable to complicate the diagram by introducing these lower-level paths.

Let me now briefly indicate how this scheme of the connexions enables us to account for some of the principal facts of binocular vision. With the exception of the facts of binocular perception of depth, of which I say nothing in this paper, the facts of binocular vision may be brought under the following three heads:—

(1) The fact of "single vision" with corresponding points—this is accounted for by the identity of their final common paths; for this means identity of motor tendency and therefore of local signature, or, in other words, it means lack of all ground for local discrimination of the sensory effects produced by stimulation of corresponding points.

(2) The reciprocal re-enforcement of processes initiated simultaneously at corresponding points—this is accounted for by the convergence to a final common path of the paths of corresponding points; for (naming the paths of the corresponding points R and L, and their final common path R L) the stream of impulses from the one path R, falling upon this final common path R L, will lower its resistances and so facilitate the discharge through it of the excitation of L.

(3) The facts of reciprocal inhibition—these are accounted for by the interconnexion of R and L in their afferent parts.

In the normal case of equal stimulation of corresponding areas with rays of similar composition, both paths R and L, in spite of their relation of reciprocal inhibition, function equally in virtue of their convergence to the final common path R L. In other cases of simultaneous and equal stimulation of paths in relation of reciprocal inhibition (as in the case of the reflex paths of antagonistic muscle groups) we commonly observe an alternation of activity of the two paths. But we may suppose that in the case of the corresponding paths the reciprocal re-enforcement secured by the final common path R L prevents this alternation of activity of the paths R L and keeps both of them open throughout the period of stimulation.

In applying the scheme to explain Fechner's paradox, it is important to note that the paradoxical darkening of the field occurs only if the more intense stimulation of the one eye (say R) is applied to it some seconds before the less intense stimulus is applied to the corresponding area of the other eye, L, and that the darkening is more marked and of longer duration the longer this preliminary stimulation of R is continued. Under these conditions, two factors co-operate to enable the less stimulated path L to inhibit partially or completely the more intensely stimulated path R—namely, (*a*) fatigue of the path R, causing increase of its synaptic resistances at r_1 and r_2; (*b*) the open state of the final common path R L, or, in other words, the low resistance of synapse $l\ r$ due to the charged or active state of the path R L maintained by stimulation of R. It may be objected that $l\ r$, like r_1 and r_2, should have its resistance raised by fatigue; but this objection is, I think, met by the consideration that lower-level subcortical synapses such as $l\ r$ seem less subject to fatigue than the higher level or cortical synapses such as r_2 and l_2.

In binocular colour-rivalry the rivalry is more vivid and fusion is more difficult, the more pure and saturated are the two colours. These facts may be fully accounted for by introducing a small complication of the scheme—namely, by assuming that the corresponding chains of retino-cerebral elements subserving the same colour qualities converge at a higher level in the efferent part of the tract than those subserving sensations of different quality. For the higher the level of such convergence, the more would the activities of the two converging paths re-enforce or facilitate one another, and the more would their tendency to reciprocal re-enforcement, due to their efferent convergence, predominate over their tendency to reciprocal inhibition due to their afferent cross-connexions. Consider, then, the case of rivalry of red and green. When pure red and green rays fall on corresponding points, the tendency to reciprocal inhibition predominates, and vivid rivalry—*i.e.*, alternating activity of the two tracts—is the rule. But, when mixed rays are applied to corresponding points, in one of which the red, and in the other the green, component merely predominates a little over the others, the tendency to reciprocal re-enforcement predominates over reciprocal inhibition, as in the case of rays of similar composition, and the rule is simultaneous activity of the paths from both retinæ and consequent fusion of the effects in consciousness of the processes initiated in both eyes, yielding a yellow of low saturation.

Closely allied with the last question is that of monocular colour fusion and rivalry. I have shown in previous publications that monocular rivalry of colours may constantly be observed under favourable conditions, of which the most important are intense stimulation and absence of re-enforcement by activity of the ocular muscles [3]. The question arises, if the paths of the one retina subserving two different colour-qualities, say red and green, are in the relation of reciprocal inhibition, as is implied by the phenomena of monocular colour-rivalry, why does fusion of their effects in consciousness occur so easily and generally, while, on similar stimulation of corresponding points, fusion is difficult, and rivalry or alternation the rule? I think the answer to this question must be that the paths of different colour-function arising from any one point of one retina have a strictly identical final common path, whereas corresponding points of the two retinæ have only partially identical final paths; for the final common path and the motor tendency of each retinal point must be conceived not as simple but as complex; and those of corresponding points must differ so far as convergent movements of the eyes are concerned, though they ar identical in respect to all other ocular movements. And the complete identical final common path may be expected to secure more efficien reciprocal re-enforcement than is effected by one only partially identical.

All the phenomena classed together under the head of predominance of contours in the struggle of the two visual fields may be explained as due to the reciprocal re-enforcement of corresponding points. Consider, as a typical simple instance of predominance of contours, the case in which a large white ground fills the whole field of the right eye, while a white stripe on a black ground runs across the middle of the field of the left eye. In the binocular field the white stripe presented in the left eye appears upon the white field of the right eye, sharply bounded by dark lines which shade off into the full brightness of the field; that is to say, the white field of the right eye is inhibited along the borders of the combined field (see fig. 3).

Or consider the case in which the white field of the right eye is evenly bright, while the similar white field of the left eye contains black lines. The black lines appear as such in the binocular field—*i.e.*, the white field of the right eye is completely inhibited in those parts which correspond with the dark lines of the left field.

These and all other instances of predominance of contours may be generalized in the statement that the parts of the binocular field that are bright to both eyes predominate over and inhibit partially or completely the parts that are bright to one eye only. This general fact is fully accounted for by the scheme; the parts of the field bright to both eyes stimulate corresponding points whose cerebral paths re-enforce one another, while the parts of the field dark to one eye receive no such re-enforcement from the other eye, and are therefore inhibited by the re-enforced parts of the same field. Or to take as a concrete illustration the case described above of a white field to right eye and a white stripe on black ground to the left eye (fig. 3): the retino-cerebral paths of the right eye corresponding to those stimulated in the left eye by the white stripe are re-enforced by the activity of these corresponding paths of the left eye which play upon the same final common paths, and therefore they are enabled to inhibit completely the activity of the paths immediately adjoining them, and less completely those of remoter parts of the right retina; hence in the combined field the black borders of the white stripe shading off into full, or almost full, brightness of the rest of the monocular field.

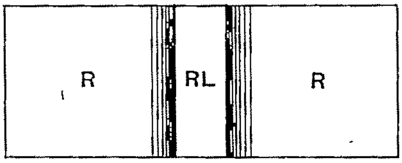

FIG. 3.

This inhibitory effect of the combined field on the parts which are bright to the one eye only is instructively displayed if the white field of the right eye is combined with a white field of the left eye containing at its centre a black circle. If this circle is small the corresponding part of the right field is completely inhibited, and the circle appears fully black in the combined field. But if the black circle of the left field is made larger by successive steps, a point is soon reached at which only its peripheral part appears black in the combined field, while its central part appears a dull grey; and the larger the circle is made the brighter becomes this central part of the circle in the combined field. This is, of course, an illustration of the rule that border contrast is stronger than ground contrast, a rule which may be stated in terms of my inhibitory theory of contrast, as follows: the inhibitory tendency reciprocally exerted by any two cerebro-retinal paths is strongest between the paths of neighbouring retinal points, and is weaker in proportion to the remoteness of the two retinal points from one another.

Another case of binocular combination akin to the last is to my mind of peculiar interest, because it seems to afford strong evidence of the truth of the hypothesis of inhibition by drainage, as well as of the scheme of relations of corresponding points suggested above. If a full white field is presented to the right eye, and to the left eye a field consisting of a black ground with a small dull grey circle at its centre, Fechner's paradoxical effect is not obtained, but rather in the combined field the area of the circle appears brighter than any part of the monocular white field, and is surrounded by a dark zone in which the monocular field is inhibited.[1] In this case, then, the activity of the paths of the left retina stimulated by the grey circle re-enforces the corresponding paths of the right eye and enables them to inhibit the paths of the most closely adjoining points of the right retina. But the point of special interest is the excess of brightness of the combined field over all parts of the monocular field. If the circle of the left field be made of an intermediate brightness—*i.e.*, distinctly less bright than the field of the right eye, but still of fair brightness—this excess of brightness of the binocular part of the field over the monocular may be very considerable.

Now we have seen that when both fields are made equally and evenly bright, the binocular field is either no brighter than the monocular field, or its excess of brightness over the monocular field is very slight, opinions being divided on the question whether it is at all brighter than the monocular field. If we neglect this questionable (in any case very slight) excess of brightness of the binocular over the monocular field, we may say that the brightness of the binocular field is no greater than that of the brighter monocular component; or, in other words, there is no psychical summation of the intensities of the monocular fields. Yet in the special case we are now considering the brightness of the binocular part of the field appears greater than that of the monocular parts; although all parts of the right retina are equally stimulated, and the stimulus to the small area of the left eye is of less intensity. We are, I submit, compelled to believe that the excitation of the paths of the central part of the right retina corresponding to the stimulated part of the left retina is somehow intensified by the simultaneous feebler excitation of that part of the left retina; and this result is fully accounted for by the principles laid down above in the following way: The excitation of the central area of the left retina facilitates the excitation or passage of the current through the corresponding paths of the right retina by playing upon their final common paths and so diminishing their resistance; this facilitation, however, would not in itself intensify the process in the cortical section of the corresponding paths of the right retina; but it enables these paths of the right retina to inhibit the equally stimulated paths of the surrounding parts of the same retina (as we see from the darkening of this surrounding area in the binocular field); and, since this inhibition is effected by drainage of neurokyme from those surrounding paths to the facilitated paths, the latter will transmit in each unit of time a larger quantity of neurokyme than they transmit under similar stimulation, but without facilitation from the corresponding paths of the left retina. The excess of neurokyme thus drained from the paths of surrounding areas and transmitted by the facilitated paths of the right retina is, then, the cause of the intensification of the brightness of the binocular part of the field. I can imagine no other way of explaining the phenomenon described, and I therefore regard it as affording strong support to the hypothesis of inhibition by drainage as well as to the scheme of connexions of corresponding points suggested in this paper.

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[1] This statement does not hold true of every moment of the observation; for the binocular part of the field is apt to exhibit fluctuations of brightness.

One other phenomenon of binocular vision seems deserving of mention here. Sherrington [14] has shown that, if two equal and corresponding parts of the two retinæ are simultaneously stimulated, one by an intermittent stimulus, the other by a steady stimulus (or by one so rapidly intermittent as to be equivalent to a continued stimulus) of less, equal, or greater intensity, the flicker is damped, or, in other words, the flicker-point of the combined fields is lower than the flicker-point of the monocular field. I suggest that this damping of the flicker of the one field by continued stimulation of the corresponding area of the other retina may be the effect of the facilitation of the discharge of the "flickering" path, by the continued stimulation of the final path common to the corresponding areas. I do not pretend to attach much importance to this suggestion, in view of our ignorance of the cerebral conditions of flicker and its extinction; my suggestion is based on the view of these conditions indicated by any observations on the effects of a single momentary stimulation of the retinæ [4]. That view is that flicker depends upon the series of discharges across the cortical synapses induced by each momentary stimulus to the retina, and that extinction of flicker occurs when the retinal stimuli succeed one another so rapidly that a fresh cortical discharge and a fresh pulse of sensation are forced at so brief an interval that the intensity of its predecessor has not perceptibly declined. I showed in the paper referred to that the pulses of sensation of lower intensity are of longer duration (flat-topped as it were); hence the flicker-point is lower in proportion as the intensity of the stimuli is lower. I suggest, then, that the facilitation or re-enforcement of the "flickering" paths by continued stimulation of the corresponding paths enables its cortical discharges to succeed one another more rapidly, or, without diminishing their intensity, gives them a longer duration or more "flat-topped" character. But these suggestions are so speculative that I will not attempt to work them out in detail. I merely throw them out for those readers who are interested in the problems of flicker.

Summary.

In the first section of this paper it is shown that the old doctrine of a "common cerebral centre" for corresponding points is wholly untenable, and that the paths of corresponding points are anatomically distinct in those central parts whose processes directly affect consciousness.

It was then shown that the secure establishment of this conclusion is necessarily fatal to Hering's theory of opponent visual processes.

A scheme of the relations of corresponding points was then suggested, according to which their paths are connected on the afferent side (like all the retino-cerebral paths of each retina) in the way which permits of reciprocal inhibition by drainage, and also at their efferent ends in a way which secures reciprocal re-enforcement. It was shown that many of the peculiar phenomena of binocular vision could be explained in terms of this scheme.

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THE PATHOLOGY OF PAPILLŒDEMA.

A Histological Study of Sixty Eyes.

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Introduction.

Our primary aim in the investigation on which the following paper is based has been to study the histological changes which the presence of an intracranial tumour may produce in the retina, disc and optic nerve. The principal type of change is that which has been known as optic neuritis, choked disc (Clifford Allbutt's translation of *Stauungspapille*), or papillœdema. We have sought to determine, as far as possible, the essential nature of this condition. During the past ten years it has fallen to the lot of one of us to examine ophthalmoscopically the eyes of nearly 700 cases of cerebral tumour in the wards of the National Hospital for the Paralysed and Epileptic, Queen Square, and in the present paper we attempt to interpret the various ophthalmoscopic features of papillœdema due to tumour of the brain, in terms of the histological changes we have found.

All the eyes examined were, with one exception, seen ophthalmoscopically by one or other of us during life; many were under observation for considerable periods before death, and full notes of the fundus changes were made from week to week. We have, in addition, examined several eyes from conditions where similar or allied changes in the disc or retina occur, and one section of our paper is devoted to their consideration. In the concluding portion we discuss the bearing of the histological changes which we describe on the arguments for and against the different hypotheses that have been advanced to explain the pathogenesis of papillœdema, and present the view that appears to us most in consonance with the facts.

The material used in the investigation has been, with the exception of one eye, obtained from cases in the National Hospital; and we are indebted to our colleagues on the staff of the Hospital for the facilities we have had in pursuing this work. We have examined in all sixty eyes from thirty-nine cases. Fifty eyes were from cases with tumour papillœdema, and the other ten were from cases of meningitis, retrobulbar neuritis, pressure atrophy, albuminuric retinitis, and retinal vascular disease. We have had specimens from every stage of papillœdema. In three cases we examined both eyes in the stage of commencing neuritis; in one of these the first signs had appeared only five days before death, and had reached a swelling of three dioptres the day before death; in another case the first change in the disc was seen within ten days of death. The majority of our patients died while the swelling was at its height. In three it had subsided into complete post-neuritic atrophy. In other cases, as a result of a decompressive cranial operation, the neuritis had subsided from different stages of its development; and finally, we had one case in which the neuritis had subsided after removal of the tumour, but had reappeared with its recurrence.

We have been fortunate in being able to remove many eyes a short time after death; in some of our most important cases they were obtained within two hours. This has enabled us to avoid the fallacies to which the examination of *post-mortem* eyes is apt to lead. The chief difficulty that meets any worker in this subject is, that the most important change, œdema, is liable to be influenced or modified, or, in the case of the nerve, even to be simulated, by the process of fixation. It has only been by the comparative examination of large numbers of sections both of normal and pathological specimens, that we have been able to form a definite opinion as to the presence or absence of certain pathological changes.

The majority of the discs were cut horizontally and parallel to the course of the entering vessels, but in five cases we cut them, along with the optic nerves, transversely in series, in order to determine the relative calibre of the vessels as they pass through the lamina cribrosa. The nerve, where possible, was examined in several different portions of its course—behind the bulb, in front of the exit of the vessels, through their exit, behind this point, in the optic foramen, and finally, in a few cases, the intracranial portion.

For the study of the general histology we used mainly hæmatoxylin, with Van Gieson's stain or eosin, but for the elucidation of certain points we employed the methods of Cajal, Bielschowsky, Marchi, Weigert-Pal, Donaggio, Unna-Pappenheim, and others. The Cajal and Bielschowsky methods were especially useful in investigating the nature of the changes in the nerve-fibres of the disc and retina.

HISTOLOGY.

A. Œdema.—In specimens from any stage of papillœdema up to its full development, but before definite signs of atrophy or subsidence have appeared, simple œdema is the one predominant feature. This shows itself by a separation of the elements of the normal tissues, both parenchymatous and interstitial, by fluid which contains no cells and which has little tendency to coagulate. The origin of this fluid we must leave for later discussion. It is the presence of this œdema, unaccompanied in the great majority of cases by any sign of inflammation either acute or chronic, which is the one unfailing histological change found in tumour papillœdema. In many cases if the œdematous fluid could be by any process removed, the tissues would to all appearance be normal. Indeed in one case of very early œdema the shrinkage which necessarily results in the process of fixation was sufficient to bring the tissues back to a condition which it would be very difficult to describe as other than normal.

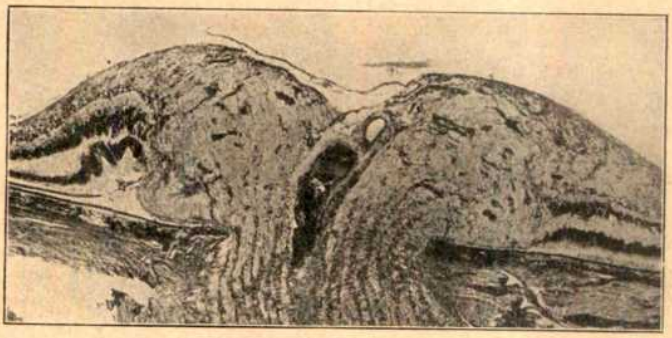

FIG. 1.

General view of papillœdema. Swelling + 5D. On the right (nasal) side of the disc the retina is merely displaced outwards; on the left it is raised and folded. Central vein congested; central pit bridged over by membrana limitans interna. Numerous small dilated vessels visible in section.

It is in the disc that the œdema produces most change. The fluid lying among the nerve-fibres and in the anterior layers of the lamina cribrosa separates and stretches these elements until they seem to form only a meshwork, in the interstices of which the fluid lies. The disc is thus increased in size in every diameter (fig. 1). The œdema appears first among the anterior layers of the lamina cribrosa, and the more peripheral bundles of nerve-fibres, and only later in the axial and intermediate bundles. As the disc swells lateralwards it displaces the retina, either raising it up from the pigment layer, or throwing it into a series of folds which run concentric with the edge of the disc. This lateral bulging is in most cases due to the distension of the most peripheral nerve-fibres alone, so that in section the whole bulge may be composed of a single nerve-bundle. The normal course of these fibres is conse-

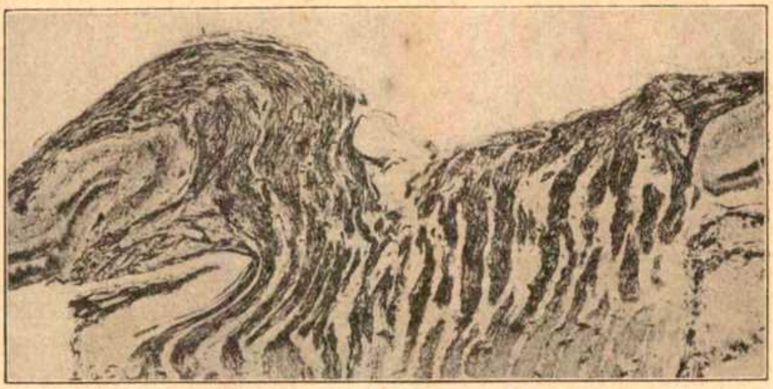

FIG. 2.

Section stained by Cajal's method to show course of nerve-fibres. On the right side the course is only slightly disturbed; on the left, the peripheral bundle of the nerve is compressed till it reaches the level of the membrane of Bruch; beyond this it is distended to form the main mass of the lateral bulge which raises the retina.

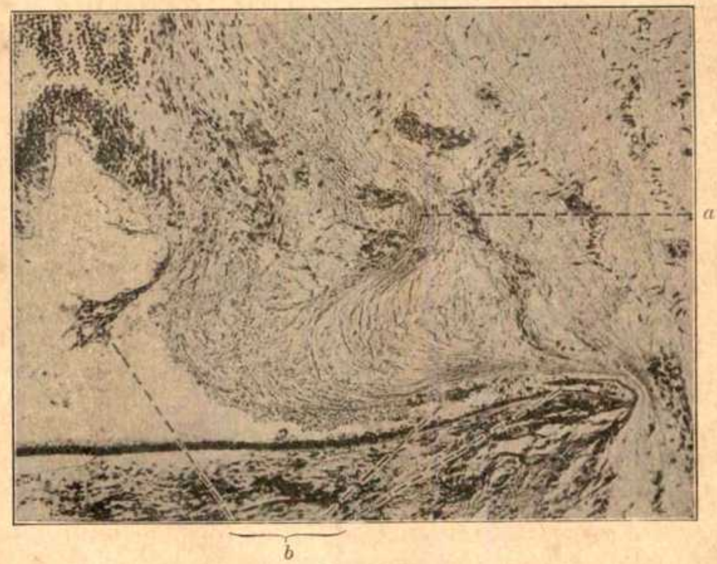

FIG. 3.

Part of fig. 1 under higher magnification. It shows the distortion of the course of the nerve-fibres which form the lateral bulge. At *a* some of the nerve-fibres are held back by vessels; *b* represents a ruptured membrane running from neighbourhood of *membrana limitans externa* towards the membrane of Bruch.

quently very much disturbed; instead of curving gently forwards to the surface of the retina they turn outwards at an acute angle as soon as they pass the corner of the membrane of Bruch. Then they double on themselves, and finally curve upwards and outwards again to the surface, so that they take an S-shaped course (figs. 2 and 3).

In raising the retina away from the pigment layer this lateral bulging of the disc occasionally ruptures a fine cellular membrane which seems to run from the membrana limitans externa to the neighbourhood of the upturned end of the membrane of Bruch. This is probably the membrane which Verhoeff has described running from the membrana limitans externa to be reflected on to the surface of the membrane of Bruch; its cellular appearance is probably due to proliferative changes consequent on its stretching when it is ruptured. The displaced fibres are frequently also ruptured, and there is then generally a greater amount of subretinal exudate. Occasionally this membrane is stretched without rupturing, and under these circumstances, while the retina may be thrown into a number of folds its inner end is not raised from contact with the pigment layer.

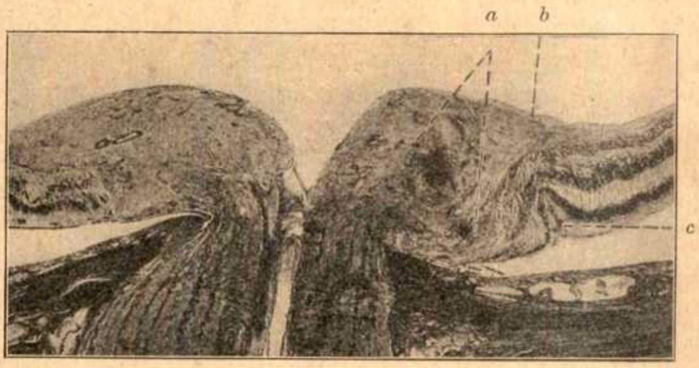

FIG. 4.

Intense papillœdema. Swelling + 7D. *a*, large area of degenerated and varicose nerve-fibres; *b*, raising of *membrana limitans interna*; *c*, folding of retina.

As the swelling increases the axial bundles are lifted upwards and inwards so as to narrow the physiological pit, and the filling in of this is completed by the œdema which raises the inner limiting membrane from the central vessels.

The course of the intermediate nerve-bundles is very little modified, and their fibres as a rule are much less separated by œdema than those of the peripheral or axial bundles.

Occasionally it happens that the separation of the fibres of a bundle is prevented in one part of its course by a band of the supporting tissue or by a vessel; when this happens to one of the peripheral bundles it adds a further complication to the distortion of its course (fig. 3). The greatest swelling and increase in the breadth of the disc as a whole takes place along a line drawn at right angles to the course of its fibres from the concavity of the first curve of the S to the upslope near the crest of the swelling; and, as will be seen, it is along this line, and more especially at either end, that the greatest changes, both degenerative and proliferative, are most prone to occur (fig. 4).

In some cases it happens, even when the swelling is at its highest point, that the physiological pit remains clear and the swelling of the temporal side of the disc is only very slight. As seen with the ophthalmoscope there may be a difference of six or seven dioptres between the level of the disc in this portion and the highest point of the swelling. Histological examination shows that this is due to the development of a specially dense band of connective tissue in the lamina cribrosa that runs from the neighbourhood of the central vessels towards the outer edge of the disc (fig. 5).

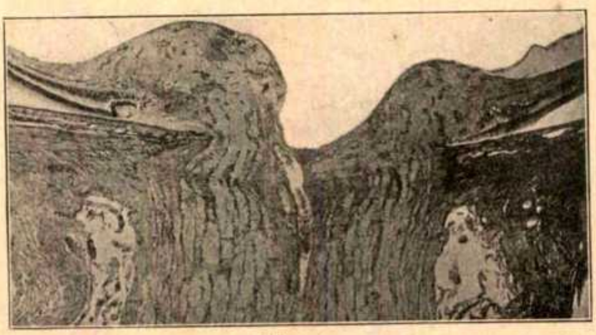

FIG. 5.

Papillœdema. Swelling + 4·5 on nasal side of disc, the central pit remaining clear.

So far we have dealt mainly with the effects of the œdema on the nerve-fibres of the disc; the changes produced in the supporting tissues are just as profound. The posterior dense layers of the lamina cribrosa are unaltered in position, and their fibres little if at all separated in the great majority of cases. They run as a compact band straight across, or with a slight convexity backwards; in one case, however, even the posterior fibres were separated a little by œdema, and had become convex forwards. On the other hand, the anterior layers become more separated the further forwards we go, so that the most anterior fibres.

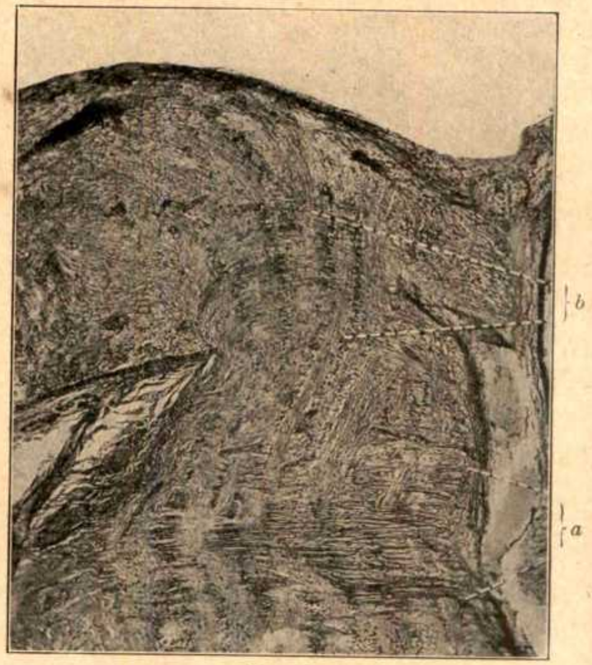

FIG. 6.

Papillœdema ten days after commencement. *a*, main mass of lamina cribrosa, normal in position; *b*, anterior fibres curved forward and separated from one another.

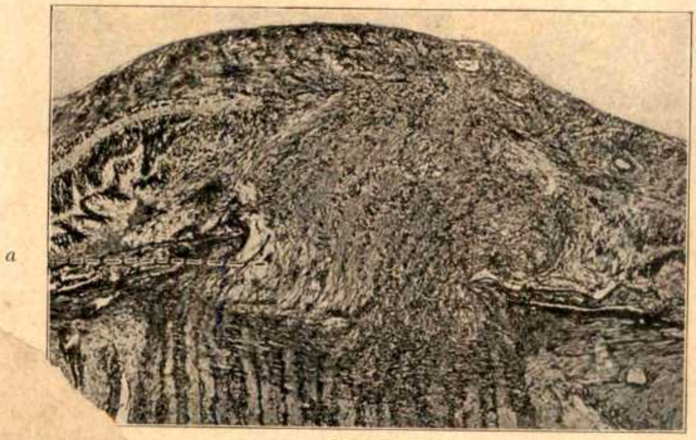

FIG. 7.

ling + 7D, lamina cribrosa slightly convex backwards. *a*, œdema es down to level of lamina cribrosa.

corresponding to the pars choroidalis, are carried out into the crest of the swelling, and so stretched and attenuated as to be barely recognizable (fig. 6). Occasionally the œdema extends behind the level of the scleral angle down to the compact portion of the lamina, and separates the nerve-fibres here from one another; but owing to the resistance that the ring formed by the membrane of Bruch offers the fibres become again compact as they pass through it (fig. 7).

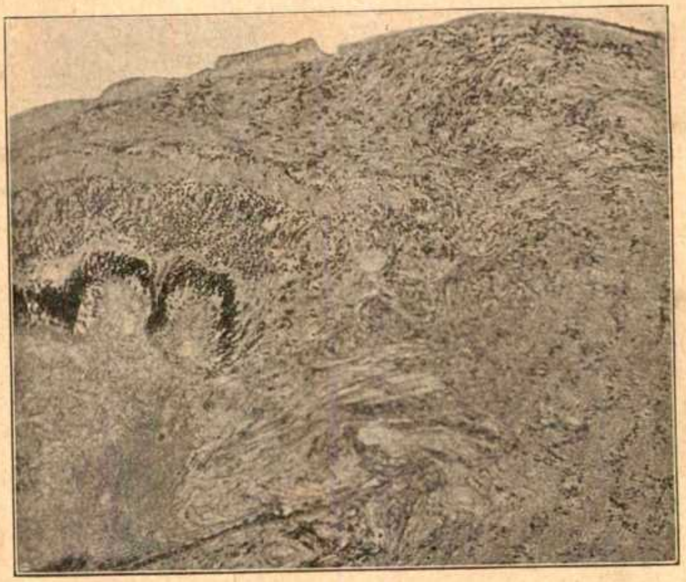

FIG. 8.

To show the rupture of fibres in the lateral bulge; folding of the retina; a few scattered cytoids; and raising of membrana limitans interna.

The separation of the fibres of the nerve-fibre layer by œdema can be traced out for a short distance in all directions. In the majority of cases the œdema remains among the nerve-fibres, but in a few of the more severe cases the membrana limitans interna is raised into small vesicles, which contain exudate, and are traversed by the stretched or ruptured fibres of Müller. These vesicles are most frequently seen towards the outer edge of the swelling on the macular side (figs. 4 and 8). They give rise to the appearance seen in cases of intense papillœdema of a fan-shaped figure of bright white dots with the apex of the fan pointing towards the macula. It is over the part of the retina in which the fibres constituting the papillo-macular bundle run that this fan lies, and it is probably because these have a short course, and consequently a limited distensibility, that the exudate makes more room for itself by raising up the membrana limitans interna.

Our observations thus bear out fully Marcus Gunn's hypothesis [21] as to the formation of the macular fan; it is produced by excess of fluid in the nerve-fibre layer which is forced into a fan formation by the anatomical arrangement of the nerve-fibres in the area affected. In an earlier paper by one of us [50] some clinical arguments in favour of this view were brought forward. The presence of a well-marked macular fan is not inconsistent with the retention of perfectly good vision; this argues strongly against it being due to degenerative changes. In cases which recover, the macular fan may disappear without leaving a trace behind, which is comprehensible if, as we believe, it is due simply to beads of œdematous fluid raising up the membrana limitans interna.

Apart from the folding and displacement the œdema produces comparatively little change in the other layers of the retina; even when they are affected it is only in the immediate neighbourhood of the disc. The elements of the inner nuclear layer may be separated so that under low magnification this appears to be made up of two layers divided by a clear space, but more usually there is only a little irregular spacing in its folded part. The outer molecular layer is often œdematous beyond the folds, but it never contains the large cavities filled with coagula that are so characteristic of albuminuric retinitis. The outer nuclear layer is rarely, if ever, affected.

A serous exudate free from cells generally lies in the folds of the retina, but the fact that we have had only *post-mortem* material available introduces a difficulty in dealing with this question of the subretinal exudate. Some of the eyes we examined were not removed till several hours after death, and the disintegration of the rods and cones had sometimes reached a fairly advanced stage, but when we managed to obtain an early autopsy these were generally well preserved. Unlike the œdema elsewhere this subretinal exudate tended to coagulate, but this may be simply the result of the presence of products of *post-mortem* disintegration or of subretinal extravasations.

To summarize: The mechanical effects of œdema within the bulb are restricted to the disc and its immediate neighbourhood, and the retina is affected only by the swelling of the disc and the spread of fluid from it.

It is more difficult to determine the presence or assert the absence of œdema in the extra-bulbar portion of the nerve. The comparatively unyielding pial sheath and the partition of the nerve by strong connective tissue septa passing from the pia must prevent any great separation of the nerve-fascicles such as occurs in the disc. I necessary, moreover, to exercise great care in discriminating betwe appearances that may be due to *post-mortem* shrinkage or to fixation and those produced by *ante-mortem* pathological processes, and it has only been by the examination and comparison of a very large number of sections that we have been able to arrive at any definite conclusion as to the distribution of œdema in the nerve.

There is frequently a definite difference between the appearance of the vessel-bearing portion of the nerve and of that part of it behind the entrance of the central vessels; indeed, this marked difference is a strong argument in favour of the pathological nature of the change found in the anterior portion. Here in some cases in which the papillœdema is considerable there is a layer of œdema immediately under the pia. It appears as a pale band made up of a meshwork of fine trabeculæ containing a few glial nuclei. It is, in fact, the normal peripheral zone of neuroglia (Fuch's *Gliamantel*) that is infiltrated by the œdema (fig. 9). This band varies in size, sometimes being as broad as a normal nerve-fibre bundle. The œdema is usually not present in the whole circumference of the nerve, or if so it may be more marked at one part than at another. There is occasionally œdema along the septa and round the axial strand containing the central vessels, but it is not as a rule so definite as in the subpial zone.

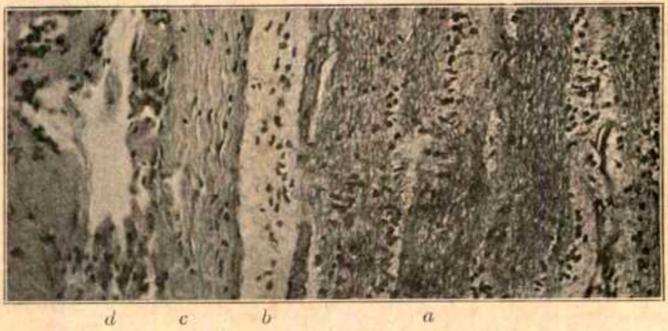

FIG. 9.

Longitudinal section of the optic nerve near the eye. *a*, nerve-fibre bundles; *b*, œdema in subpial zone (*Gliamantel*); *c*, *pia mater*; *d*, subarachnoid space.

The œdema of the nerve diminishes rapidly at the entrance of the central vessels and usually disappears a little behind this point. We were never able to detect any œdema in the intracranial portion of the nerve.

B. The vascular changes.—The vascular changes in papillœdema consist mainly in venous and capillary congestion. The arteries, at least in the pre-atrophic stages, seem to be unaffected. The effects of this venous and capillary congestion are, like the œdema, most obvious in the disc itself and in its immediate neighbourhood. The larger veins in the disc are dilated, usually full of blood, which often contains an excess of polymorphonuclear leucocytes. In the zone of the swollen disc which corresponds to the anterior layers of the lamina cribrosa there are numerous small dilated venules and capillaries, most numerous at a point just inside the lateral bulging of the nerve-fibres. Evidences of capillary and venous congestion may be also seen in the retina, especially in the nerve-fibre layer, for a short distance from the disc margin. Beyond the radius of the macular region there is usually little obvious change. The central vein in its passage through the denser part of the lamina cribrosa shows no dilatation; its lumen is smaller than in the looser tissues in front, but this seeming diminution is only relative, and is due to the fact that the more unyielding tissue of the lamina prevent its dilatation. In the looser tissues behind the lamina it again dilates and as a rule remains dilated in the whole of its intraneural course. It passes from the centre of the nerve towards the pia usually before the artery and often winds round the nerve under the pial sheath. In this part of its course its lumen is still generally well open, but after it has passed through the pia and is lying in the subarachnoid space its walls are collapsed and its lumen is simply a slit (figs. 10 and 11). Traced in serial sections it is found to remain in this condition in its passage through the subdural space and in the dura mater until it reaches the looser tissues in the outer part of the sheath. The numerous smaller veins and the capillaries in the pial sheath and in the septa are also in a condition of congestion.

A further evidence of vascular congestion is afforded by the hæmorrhages which may occur everywhere on the disc and in the retina in its immediate neighbourhood. They are most frequent on the outer slopes of the swelling or just beyond it; only in very severe cases are they found at any great distance from it. They are seen most frequently as scattered red corpuscles lying along and amongst the nerve-fibres (striate hæmorrhages). In specimens stained by Cajal's method it can be seen that the nerve-fibres generally remain normal, and are merely separated by the extravasated blood; but in and around larger hæmorrhages they often present the degenerative changes dealt with later.

Frequently the hæmorrhages raise the membrana limitans interna from the nerve-fibres, in one case to a height exceeding that of the whole retina. These blot hæmorrhages resemble the œdema vesicles in that they are most frequent on the macular side of the disc, but they may occur anywhere on or around it.

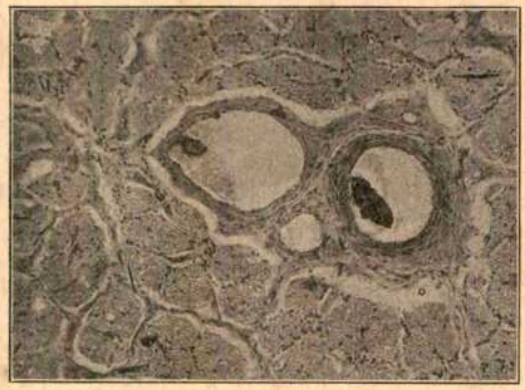

FIG. 10.

Cross-section of the central vessels in the centre of the nerve immediately before the exit of the vein, showing vein fully distended.

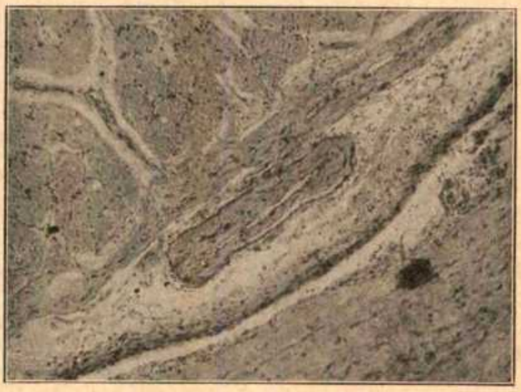

FIG. 11.

Section of the same vein in the subarachnoid space.

Hæmorrhages also occur in the outer molecular layer just beyond the retinal folds. In the other retinal layers they are less frequent, and when present are mostly due to extension from the nerve-fibre layer or outer molecular layer. A considerable number of red blood cells are commonly found in the subretinal exudate.

While the hæmorrhages are chiefly due to the venous congestion it is probable that another factor plays at least some part in their causation. An abrupt fungiform swelling of five or six dioptres must cause great mechanical stretching of many of the smaller vessels, and consequently produce a liability to rupture. The fact that the most frequent site of hæmorrhage is on or just beyond the downslope of the swelling seems to indicate that this is at least a factor in producing the hæmorrhages.

The vascular changes that occur in the later stages of papillœdema are most obvious in the papilla. The capillaries and smaller vessels, which in the earlier stages are engorged, become occluded by endothelial proliferation (fig. 16). The adventitial sheath of the larger vessels becomes considerably thickened and occasionally undergoes a form of hyaline degeneration. These vascular changes, which can be best interpreted as the results of an earlier congestion, extend down to the lamina cribrosa, but in the nerve behind this they are not so marked and may be absent.

There was no evidence of any general choroidal congestion; in a few cases there was a slight congestion of the choroidal veins in the immediate neighbourhood of the disc, probably due to their anastomosis with the engorged vessels in the anterior part of the lamina cribrosa.

C. Inflammatory changes.—Various writers on papillœdema describe inflammatory changes as the essential and characteristic feature of the condition, while others have found no evidence of inflammation in the majority of the cases they have examined. This discrepancy must be evidently largely due to differences in the conception of what the term inflammation connotes; some definition is consequently necessary, or rather a statement of the histological changes that can be accepted as indicative of it.

The usual definition of inflammation is the reaction of irritated or damaged tissues that still retain vitality. The histological changes that constitute this reaction are an active engorgement of the vessels, an exudation of fluid into the affected tissue, an infiltration of leucocytes, combined with proliferation of certain fixed tissue cells, and invasion and multiplication of wandering cells. In inflammation of long standing or of low grade, one or more of these features may be absent.

In the nervous system, however, inflammation shows certain peculiarities, as the structures of epiblastic origin—i.e., the functional elements and the neuroglial supporting tissues—do not take an active part in the process, which is consequently limited, at first at least, to mesoblastic tissues, that is, the blood-vessels and the little connective tissue they carry with them from the leptomeninges.

Not only is the constituent portion of the nervous system that is involved by inflammation thus very small, but there is also a remarkable independence of the epiblastic and mesoblastic portions in pathological processes, so much so that Nissl and others assume a hypothetical *Grenzmembran*, or frontier between them, through which a pathological process does not readily break.

This relation explains the fact that in slighter inflammation the characteristic histological changes are entirely limited to the vessels and the connective tissue that surrounds them, and that only the destructive effects that accompany or result from it are visible in the nervous tissue itself. If, however, these destructive changes become more intense, the cellular infiltration that had been hitherto perivascular may break into the epiblastic tissue. On the other hand, the fluid exudate may, at an earlier stage, or in slighter degrees of affection, percolate the nervous tissue itself.

Long-standing œdema of any tissue, especially when it produces degenerative or destructive changes in the parenchyma by mechanical distension or nutritional disturbance, may lead to a thickening of the vessel walls and of the supporting matrix, and even slight cell infiltration, which may be easily confused with an inflammatory process, or a secondary inflammation of low grade may occur. Thus, even when inflammatory changes are present, it must be decided whether they are primary or secondary.

The chief change that we have observed in the nerve-head or retina in optic neuritis that can be interpreted as evidence of inflammation is a slight small round cell infiltration into the connective tissue sheath of some of the vessels. This is always small in amount when it does occur, and is generally present around only one or two vessels in any disc. It is most commonly seen in the loose connective tissue around the first branching of the central vessels, but it occasionally extends some distance along one, or a few of the branches. We have also seen it in the adventitial sheaths of the vessels as they pass through the lamina cribrosa, but very rarely round the central vessels in the retrobulbar portion of the nerve. We did not find any trace of infiltrating cells in the septa of the nerve.

These infiltrating cells, when present, lie in the sheath itself, apparently in the Virchow-Robin space; they are never actually perivascular. They are always of the small lymphocyte type, though we occasionally saw cells with similar nuclei but surrounded by more cytoplasm in the loose and œdematous tissue around the central vessels. We never recognized any polymorphonuclear cells or definite plasma cells among these lymphocytes.

Though practically all our optic discs were examined in almost serial sections, we never observed this cellular infiltration spread or break from the perivascular connective tissue into the parenchyma; and we have nowhere found any cellular infiltration among the nerve-fibres, or elsewhere in the nerve or retina.

As a rule there is no noteworthy proliferation of the fixed tissue cells of the adventitial sheath associated with the small round cell infiltration, but the fact that in the later stages of the neuritis, or in discs in the state of consecutive atrophy, there is an increase of perivascular connective tissue, makes it imperative to regard some of these cells as fibroblasts.

This small round cell infiltration was present in only a relatively small proportion of our cases—in less than a quarter. Further, it was found only in cases of relatively long standing, in which the papillœdema had been intense. This, combined with the fact that when present it was generally surprisingly local, and could be often seen around only one or two small vessels in a disc, makes it impossible to assume that it constituted the primary pathological process. On all these facts it appears much more probable that, even if accepted as evidence of inflammation, these locally restricted changes represent only a reaction of the tissues to the degenerative and destructive effects which result from some other pathological process.

The only other histological changes we found that could be interpreted as inflammatory were the vascular engorgement, the œdema, and the degenerative changes in the nerve-fibres; these changes can be, we believe, more satisfactorily regarded as non-inflammatory in their origin.

Certain authors, as Liebrecht [35], Elschnig [15], and Lawford and Edmunds [32], have described as an important pathogenic factor in optic neuritis a perineuritis of the nerve-stem, from which the inflammatory process invades the nerve and produces therein certain degenerative changes. This term can only mean a meningitis of the pial sheath, and of this there was no trace in any of our cases, excepting in those of general meningitis in which the disease had spread into the optic sheath. The probable effect of such a perineuritis or meningitis on the optic nerve, if it did exist, can be best estimated by analogy with the changes a local or a general meningitis evokes elsewhere in the nervous system in the underlying tissue. And it is now generally recognized that a surprising feature of meningitis is the little change that may occur here, for as a rule the inflammatory cell infiltration does not break through the pia mater. If it extends inwards it is only along the vessel sheaths; and it produces at the most a superficial œdema of the brain, and frequently even this is absent or very slight. A meningitis that can produce it must be infinitely more intense than has been described or figured in the optic sheath by the authors who have postulated this as a causal factor of papillœdema.

The fact that in some of our cases of meningitis, in which the inflammatory processes extended into the optic sheath, the ophthalmoscopic and histological features of the disc changes were identical with those of tumour papillœdema, make it improbable that even in this small group the perineuritis which existed could have contributed to its pathogenesis.

It appears to us that a strong argument against the views of those who assume a "descending inflammation" or an inflammatory perineuritis as a casual factor in papillœdema is the fact that acute and extensive inflammatory lesions may exist in the optic nerves, as in a case we examined, and yet produce no trace of optic neuritis; in fact it is only rarely that retrobulbar neuritis produces any swelling of the nerve-head; and then only when the inflammatory focus lies in the nerve near the bulb.

We have had the opportunity of examining histologically such a case of retrobulbar neuritis, which had been observed from its commencement by one of us.

K. P., aged 35. In September, 1908, following an operation on the right turbinate bones, there was infection of the right sphenoidal sinus. Three days later she developed a large absolute central scotoma of the right eye, and the characteristic signs of retrobulbar neuritis. The disc and fundus presented no abnormal changes. Within two months there was a considerable recovery of the periphery of the field, but a small central scotoma remained; the disc had become pale, and its vessels small. In the beginning of February, 1909, she suddenly developed signs of an acute meningitis which led to a fatal termination five weeks later. To the end the right papilla showed no trace of swelling, but only the features of a primary atrophy; but a definite papillœdema of the left disc developed. *Post-mortem* examination revealed a general pneumococcal meningitis, most intense on the base of the brain.

Microscopical examination of the left eye showed an early papillœdema, while in the right eye, though there was an inflammatory lesion in the nerve near the foramen and small round cells in the sheath, there was no trace of œdema of the papilla, but only the histological features of a retrograde atrophy.

By the careful study of our sections we are forced to the definite conclusion that the histological characters of papillœdema, no matter in what stage of its development it may be examined, are not those of an inflammatory process. The indications of inflammation that are occasionally found in intense or prolonged papillœdema are such as only justify the assumption that if any true inflammation exists it is merely secondary to the disturbance produced by the œdema. Our material has been so large that we can only assume that the authors (Leber [33], Gowers [18], Deutschmann [10], Elschnig, [15 and 16] Lawford and Edmunds [32], &c.) who have described papillœdema as an inflammatory process have been misled by the histological appearances, and especially by mistaking proliferated neuroglial and other nuclei for infiltrating cells. If this glial proliferation be so misinterpreted its association with vascular congestion and œdema may easily lead to the erroneous assumption of an inflammation.

D. The nerve-sheath.—Considerable attention has been almost invariably paid by previous writers to the state of the nerve-sheath in papillœdema, and different pathological changes have been described within it. Like most of these authors, we frequently found considerable dilatation of the sheath, especially in that portion of it near the bulb, while posterior to the exit of the vessels and near the optic foramen it was less distended; consequently when the eye was carefully removed the sheath presented the contour of a leek, gradually becoming larger towards the bulb, but again suddenly constricted immediately posterior to it. Unhappily we have not detailed descriptions on this point made at the autopsy for each eye, and we are therefore unable to give the percentage of cases in which various degrees of this distension was present, and deductions on it drawn from fixed and hardened specimens would be evidently unreliable.

It seems, however, to have no constant or close relation to the stage or intensity of the neuritis, and is as marked in some of the early cases as in late cases of great intensity. The subarachnoid space is chiefly distended, and when the dilatation is great the arachnoid is pressed against the dura mater; some strands remain attached to the pia mater, while others are probably ruptured. Usually this space contains no visible substance, but occasionally a coagulated exudate is visible within it, as though its fluid were more highly albuminous than is the rule. (It may be mentioned in this connexion that when cerebrospinal fluid is cut off from the general cerebrospinal circulation, as it may be in the lower portion of the spinal theca by a tumour, it often becomes so highly albuminous that it may undergo spontaneous coagulation [7 and 44].) In two cases there were small hæmorrhages in the sheath.

We observed no noteworthy changes in the dura mater, but there was frequently, especially in the more chronic cases, a considerable proliferation of the endothelial cells of the arachnoid, and even a thickening of its fibrillæ. There was, however, never sufficient thickening or contracture to threaten compression of the nerve.

In attempting to interpret the nature and origin of this change it must be remembered that even in normal specimens the development of the arachnoid varies considerably. The thickening is certainly not inflammatory, at least, it was not associated in any stage with any evidence of inflammation. The cellular proliferation is more probably a result of the distension of and stasis in the sheath, and the consequent nutritive disturbance. A similar thickening of the arachnoid is often seen over the spinal cord unassociated with inflammatory changes.

The pia mater usually presents no pathological changes, excepting the œdema of its inner layer which has been already dealt with. Small round cell infiltration was present in only one of the cases of tumour papillœdema we examined, and here there was only one small patch of infiltrating cells. No other definite evidences of inflammation were present in any of these cases.

In three cases of meningitis with papillœdema, one tubercular and two purulent, some of the characteristic infiltrating cells were present in the subarachnoid space of the nerve-sheath; in the tubercular case they were chiefly small mononuclear, large mononuclear, and large hyaline cells; in the purulent specimens polymorphonuclear cells. In fact, the meningeal change had extended to the optic sheath. Despite this, there was very little evidence of inflammatory changes within the nerve, though the subpial œdema was marked.

E. Degenerative changes.—The chief degenerative changes of papillœdema are limited to the functional tissue of the disc and nerve, that is, the nerve-fibres, while in the supporting tissues only secondary changes of a reparatory or sclerotic nature occur.

These changes in the nerve-fibres can be naturally divided into the *primary degenerations* that result directly from the pathological process, whatever it may be, or the mechanical or nutritive effects that it produces; and the *secondary or Wallerian degeneration* that occurs in the cerebralward portion of fibres, the continuity of which has been interrupted.

The primary degeneration is naturally most pronounced in the regions where we find the greatest disturbance of the nerve-fibres by the œdema and swelling, that is, near the surface of the swelling, and in the large lateral bulging of the nerve-fibres. But when there is much œdema these changes can be seen across the whole area of the disc (fig. 12).

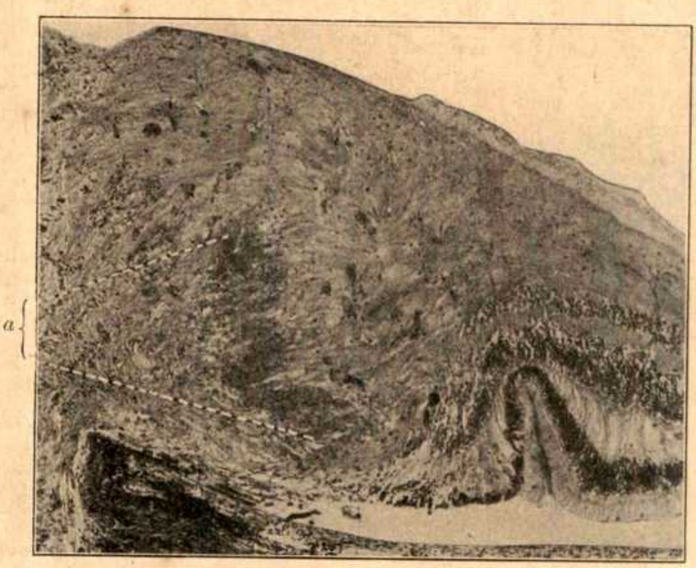

FIG. 12.

(From same case as fig. 4, different section under higher magnification.) Shows large area of degenerating nerve-fibres, *a*.

Their earliest appearance varies according to whether they occur where the fibres lie compactly arranged, or separated from one another by the œdematous fluid. In the former case, as among the intermediate fibres, ordinary hæmatoxylin and Van Gieson or eosin stained preparations occasionally show an area opaque and almost homogeneous in appearance, and on examination under higher magnification this is seen to be due to the tight packing together of swollen and varicose fibres. The enlargement and irregular contour of the individual fibres is more easily seen where they are separated from one another by the fluid exudate, as in the lateral bulging that displaces the retina.

But as these nerve-fibres are naked axis cylinders, other methods are necessary to demonstrate accurately the changes they undergo; we consequently employed the methods of Cajal and Bielschowsky in the examination of six eyes, and by their aid, and especially by Cajal's method, it was easy to determine their exact nature. The swelling generally begins at one spot in a fibre, but there is often an irregular increase of its calibre over a certain length. It results from a local increase of the interfibrillar protoplasm which separates the fibrils from one another, as a rule in such a way that these seem to lie in the periphery of the swollen fibre (fig. 13).

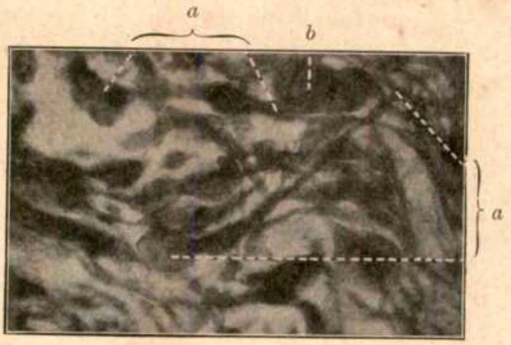

FIG. 13.

Preparation of nerve-fibres in disc, stained by Cajal's method. *a*, nerve-fibres showing varicosities and terminating in bulbous swellings; *b*, fully developed cytoid body at end of varicose nerve-fibre.

As the swelling increases in diameter the neurofibrils become disintegrated and disappear. From this stage these degenerative changes in the fibres develop rapidly, but in suitable preparations their evolution can be easily followed. As a rule, in a certain portion of the affected fibre the swelling increases and forms a spindle, continuous at each of its poles with the nerve-fibre, but as it increases further in diameter and becomes more globular it frequently loses its visible continuity with it, or a rupture occurs at its central end, so that it remains for a time attached only to the distal portion of the fibre on which it has developed (fig. 14). Often, however, they can be seen lying isolated in the nerve-fibre layer as more or less homogeneous colloidal bodies. Each contains, as a rule, at or near its centre, a core with a relatively sharp margin resembling a nucleus, but distinguishable by its highly refractile appearance, its homogeneity, and its staining properties (fig. 15). In hæmatoxylin and Van Gieson preparations this core takes a brownish-violet tint, with Unna-Pappenheim's pyronin-methyl green mixture a bright pink, and with the reduced silver stains of Cajal and Bielschowsky a homogeneous black. None of the methods we employed revealed any structure within it. In shape, too, this core is often quite dissimilar from a nucleus; for instance, we have seen one extend into both, or lie between two, bulbar enlargements on a fibre, and occasionally one appears as an elongated cylindrical structure.

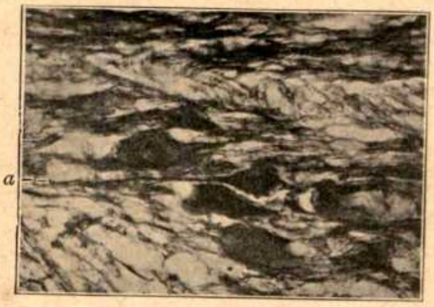

FIG. 14.

Nerve-fibres and cytoid bodies stained by Bielschowsky's method. *a*, a nerve-fibre continuous with a cytoid body.

The body is often somewhat rarefied or finely granular immediately around the core; in ordinary hæmatoxylin or aniline stained sections the rest is usually homogeneous, but in preparations in which the neurofibrils are stained it often appears finely granular, as if it contains the detritus of the disintegrated fibrils, and occasionally a trace of meshwork appearance is seen as though the neurofibrils had not completely broken up.

These structures are evidently the so-called "*cytoid bodies*" frequently described in the retina in pathological conditions, especially in albuminuric retinitis, vascular lesions, and in the neighbourhood of local injuries. They have been carefully studied in the latter condition, especially by Tepljaschin [60] and Parsons [48]. We compared those that occur in the two former states with those we found in papillœdema, and were unable to detect any essential difference between them. They have been previously described in papillœdema by several writers. They are most frequently seen near the apex of the swelling, or in the lateral bulge of the papilla, but can be found in practically every part of the disc; in very few cases, however, are they situated near the main mass of the lamina cribrosa, or behind the level of the choroidal angle, and in papillœdema they rarely lie far beyond the margin of the disc. They occur only among the nerve-fibres, and never in the nerve behind the lamina cribrosa.

We have devoted a considerable space to the description of these bodies, as it is unquestionably they that have been recently described as macrophages [27], though they have been generally regarded as degenerated nerve-fibres, or *varikös-sklerotische Sehnervenfasern* (*cf.* figs. 15 and 17).

Our observations confirm unequivocally the latter view, and so many different arguments support it that it appears to us to be beyond doubt. The danger of confusion can exist only when the fully developed cytoid bodies are studied by inadequate methods, but though these may have a superficial resemblance to cellular structures their cores have neither the histological characters nor the staining properties of the nuclei of any variety of cells that are found in the eye or in the nervous system, in either normal or pathological conditions. The fact that they occur only in the nerve-fibre layer is also strongly in favour of their origin from nerve-fibres. Further, as we have already described, it is frequently easy to see in even ordinary preparations that in the early stages of their development at least they are continuous with nerve-fibres, and their relation to the fibres, and their mode of development from them, may be more definitely determined in discs treated with the specific axis-cylinder methods of Cajal and Bielschowsky. By both these methods the cytoid bodies take the same colour as the normal

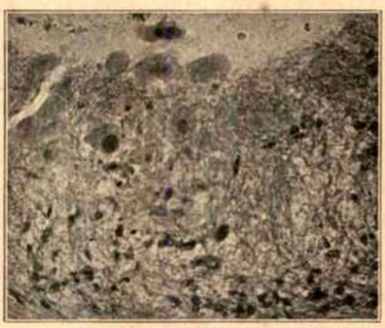

FIG. 15.

Cytoid bodies lying free near the surface of the disc (stained by hæmatoxylin and Van Gieson's stain).

axis-cylinders, even when we cannot demonstrate their continuity with these.

Finally, we treated one eye by Donaggio's method, by which only recently degenerated fibres are stained, and the rest of the section remains colourless; in this eye only the cytoid bodies were coloured. In another eye that had been fixed in Müller's fluid and stained by Weigert-Pal's method, the earlier cytoid bodies contained blue granules, while in those in the later stages of development the granules were a brownish-yellow.

These various arguments, we believe, leave no doubt that these so-called cytoid bodies represent portions of degenerated nerve-fibres, and are not macrophages, as they have been recently described, nor degenerated leucocytes, as Litten [37] and Greeff [22] believed.

Cytoid bodies are rarely found in the later stages of papillœdema when it has subsided into atrophy. Their disappearance can be readily observed in suitable preparations; they first become pale and more globular, and in such a disc treated by Marchi's method coarse and irregular fat globules are found within the clumps, and even within the cytoids themselves. Thus they evidently undergo a fatty or lipoid degeneration when they reach a certain stage of development, as Parsons has already shown. It appears probable, though we cannot make the statement with certainty, that they all disappear by undergoing this type of degeneration.

This varicose swelling of the nerve-fibres and the ultimate development of cytoid bodies from some of them was the main degenerative change we observed in the disc. As its nerve-fibres are naked axis-cylinders the Marchi method naturally revealed no change beyond the lipoid degeneration of the cytoid bodies.

The immediate cause of this form of degeneration must be briefly considered. There are evidently three possible pathogenic factors: the first is the stretching and tension to which the nerve-fibres are subjected owing to their displacement by the œdema; secondly, it may be due to imbibition by the fibres of the œdematous fluid in which they lie; and finally, it may result from the nutritive and circulatory disturbances, that result directly from the œdema.

It is not possible to exclude the latter two factors, but certain observations make it very probable that the stretching of the fibres owing to their displacement has a very important influence. In the first place, as we have already described, this varicose degeneration of the fibres occurs most commonly where these are subjected to the greatest tension, *i.e.*, on the surface of the disc and in its lateral bulging; but a more important observation which we could repeatedly make was the fact that where a bundle of fibres was held back by, and consequently bent at an angle over, a vessel or a band of supporting tissue, these portions of the fibres, and most frequently that lying on the central side of the obstruction, presented this change (fig. 16). This was generally so remarkably local that there can be no doubt that the pressure and the stretching of the unsupported portions of the fibres was an important factor in its causation. On the other hand, this form of degeneration may be found in places, as in the centre of the disc or immediately in front of the lamina cribrosa, where the nerve-fibres cannot be subjected to much local tension. The frequent occurrence of cytoid bodies in the neighbourhood of hæmorrhages, by which the fibres had been probably damaged, and as we have been able to observe in other cases, in the neighbourhood of vascular occlusions, and in albuminuric retinitis, makes it impossible to assume that such local stretching is always the main cause of the degeneration; it would probably be more correctly regarded as a predisposing factor.

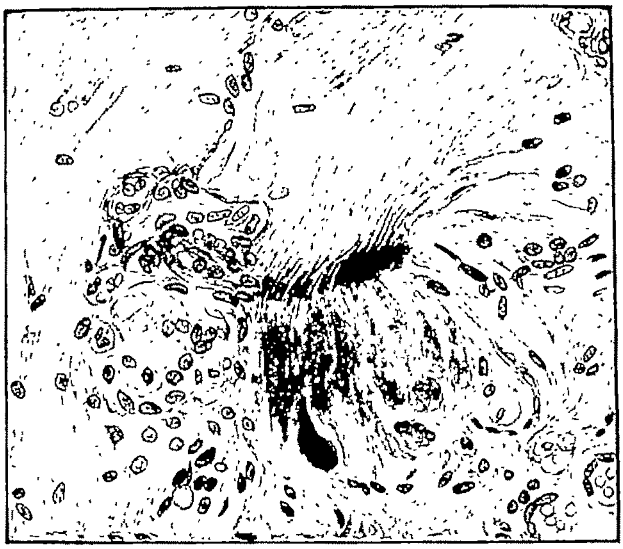

FIG. 16.

(Drawing.) Shows a bundle of nerve-fibres held together by small blood-vessel and bent over it; development of varicosities and cytoid bodies on central side of obstruction. Shows also endothelial proliferation in walls of smaller vessels.

The neuroglial elements of the disc and retina do not suffer degenerative changes; but swollen neuroglial cells with pale or granular cytoplasm (*Körnchenzellen*) may be seen in the œdematous areas of the nerve-fibre layer.

On treating the retrobulbar portion of the optic nerve by Marchi's method, as we did in a few cases, two distinct types of change were found. The first was represented by fatty globules stained black by this method arranged along the course of the fibres; this evidence of secondary or Wallerian degeneration was very uncommon, as might be expected, as at the most only a small proportion of the fibres can be interrupted in their course. The second type was represented by fine granules, often dark brown instead of black, scattered diffusely throughout the cross-section of the nerve, and not arranged in chains along the course of the fibres. Elsewhere in the central nervous system this appearance is taken as an indication of a primary diffuse degenerative change in the myelin sheaths due to toxic or nutritive causes, and it seems to us most probable that it was of this nature in the optic nerve also, and that it resulted from the nutritive or circulatory disturbances. In the latter stages of papillœdema we were able to demonstrate a degeneration or atrophy of bundles of fibres in the nerve by Weigert's method. The affected bundles generally occupied a crescentic area on one side of the nerve, and it was often possible to trace the continuity of these atrophied fibres with those most involved in the lateral bulge.

No prominent degenerative changes could be observed in the retina during the acute stages of papillœdema, though there might be a local destruction of certain elements of any layer by hæmorrhages or by the tension they are subjected to by the folding or swelling of the retina near the papillæ. In or around the site of such a hæmorrhage large inflated cells, which evidently act as scavengers or macrophages, could be observed (fig. 17). As the greater part of our material was obtained some hours after death, it is difficult to make a positive statement on the affection or escape of the rods and cones, but in freshly obtained material we could detect no definite evidence of degeneration of them.

In the stage of atrophy the ganglion cells are considerably diminished in number, and those that remained are often shrunken in size; we have not, however, observed any acute degeneration of these, and from their appearance conclude they have merely undergone the secondary atrophy which supervenes in the cells of central nervous system when the fibres that spring from them degenerate.

F. Sclerotic changes.—An optic disc in the state of atrophy consecutive to a papillœdema is characterized by general shrinkage and a diminution in the number of its nerve-fibres, combined with a proliferation of neuroglial nuclei, and an increase of the neuroglial fibrils that form its matrix. In addition, there is generally an increase of the connective tissue that surrounds the vessels.

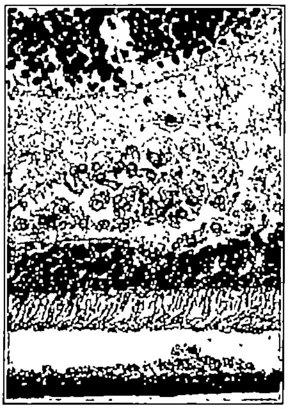

FIG. 17.

(From same section as fig. 15.) Macrophages in the site of an old hæmorrhage in the outer molecular layer. (Note the difference in the appearance of nuclei from the core in the cytoid bodies in fig. 15.)

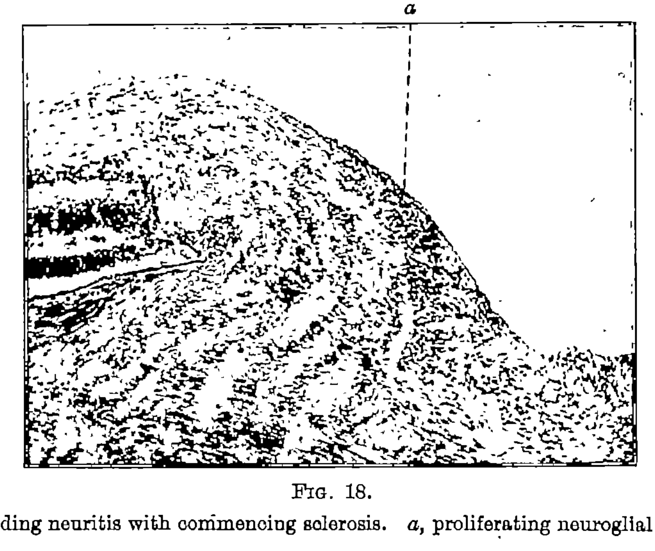

FIG. 18.

Subsiding neuritis with commencing sclerosis. *a*, proliferating neuroglial nuclei.

The development of these changes can be followed from the time in which there is yet considerable swelling of the papilla. Their earliest evidence is a proliferation of the neuroglial nuclei, visible first, as a rule, near the apex of the swelling around the central pit. This neuroglial proliferation coincides with the diminution of the œdema and soon gives rise to a prominent mass of nuclei in this region (fig. 18). The nuclear proliferation apparently occurs by direct division, and these nuclei are distinguishable from the normal neuroglial nuclei of this region only by their slightly greater size, and by the coarser chromatin granules they contain. It is followed by an increase of the neuroglial matrix, the fibrillæ of which are definitely coarser than normal.

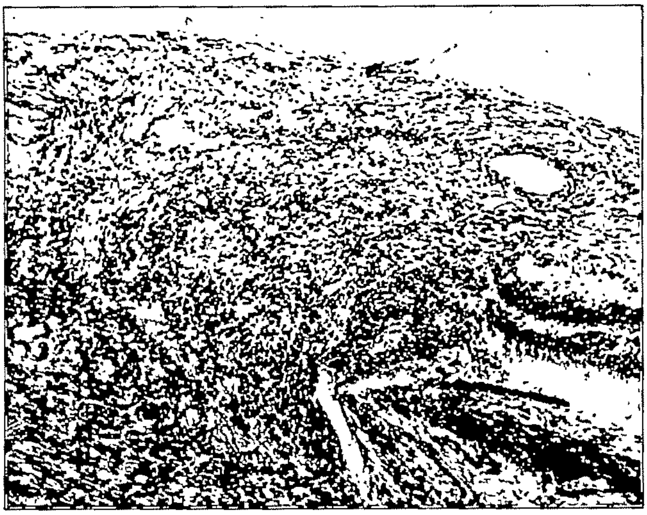

FIG. 19.

Advanced post-neuritic atrophy with marked neuroglial sclerosis.

About the same time, or later, a similar proliferation of the nuclei and fibrillar elements of the neuroglia can be seen in the lateral portion of the disc among the distorted nerve-fibres that displace the retina. Here it generally occurs first in and around some of the bands of supporting tissue that are drawn outwards, and often there results an islet of sclerotic tissue that lies in or on the inner side of the main mass of the lateral bulging. At a somewhat later stage, as the œdema subsides, this neuroglial sclerosis spreads over the rest of the disc; it first becomes apparent by the increase of the nuclear columns that lie between the bundles of fibres after these have passed through the lamina cribrosa (fig. 19).

As it becomes general throughout the disc this neuroglial sclerosis rapidly leads to shrinkage, at least in cases in which there has been considerable œdema and destructive change. A noteworthy result of this shrinkage is that, by it, the retina that had been displaced outwards by the œdema is again drawn in, and occasionally in much atrophied discs beyond its normal limit. This shrinkage probably produces a degeneration or rather an atrophy of nerve-fibres that have hitherto escaped damage; at least, there can be no doubt that the diminution in the number of fibres in the stage of atrophy is always much greater than that which we have ever seen in a disc in which the œdema and consequently the destructive processes are subsiding, but in which sclerosis had not yet become pronounced.

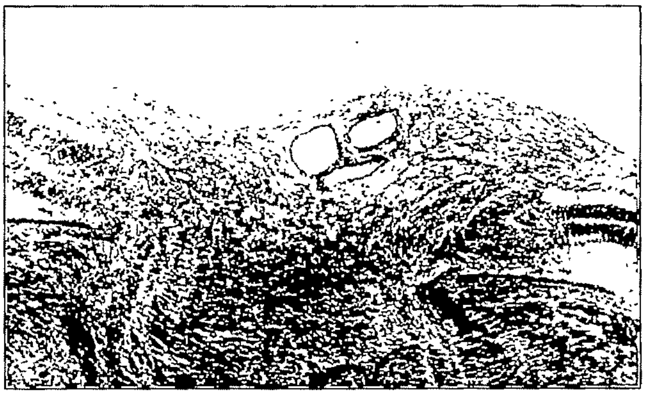

FIG. 20.

Section from same case as fig. 19, under a lower magnification, to show the thickening of the lamina cribrosa.

The neuroglial sclerosis in the stage of atrophy leads to a noteworthy change in the histological appearance of the disc, as it obliterates the normal striate appearance of vertical sections, which is due to the course of the nerve-fibres or of their bundles parallel to one another.

This coarse neuroglial sclerosis generally extends only a short distance from the disc into the nerve-fibre layer of the retina.

As we have had the opportunity of examining eyes in which the papillœdema was relieved by a cranial decompression and *had* subsided without serious deterioration of vision ensuing, their histological appearances may be contrasted with those in which secondary atrophy had supervened. In a few of these cases, though intense papillœdema had existed, the histology of the disc and retina was practically indistinguishable from the normal; in other cases the only noteworthy deviation from the normal was the existence of a slight sclerosis in the regions of the disc in which the sclerosis as a rule commences (fig. 18).

From its character, as well as its mode of development, there can be no doubt that the neuroglial sclerosis of the atrophying papilla is purely secondary to the damage produced directly by the œdema, and to the mechanical and nutritive disturbances it occasions.

The main part played by the mesoblastic tissues in the sclerosis of an atrophying disc is a thickening of the outer sheaths of the vessels; no new connective tissue is laid down elsewhere in the disc. A considerable thickening of the main mass of the lamina cribrosa is often apparent in the later stages of papillœdema, and especially in advanced atrophy (fig. 20).

The degeneration or atrophy of bundles of nerve-fibres in the optic nerve in the later stages of papillœdema is followed by a characteristic secondary neuroglial sclerosis, with an increase of both the nuclear and fibrillar elements, within and around them. It is generally accompanied by a thickening of the connective tissue septa of the nerve; this, like the neuroglial sclerosis, is purely secondary to the degeneration, and we never obtained any evidence that it was preceded by or resulted from an inflammatory process.

THE NATURE OF TUMOUR PAPILLŒDEMA.

The careful examination of the material at our disposal permits us to express a definite opinion on the nature of optic neuritis.

The essential change, as we have described, is an œdema that separates the nerve-fibres in the disc and its neighbourhood, but rarely invades the retina; it produces the swelling and the other characteristic ophthalmoscopic features. The hæmorrhages that occur are partly due to the stretching and rupture of the small capillaries that are involved in the swelling, and partly to the associated venous engorgement.

On the other hand, in the great majority of our cases there was no evidence of any inflammatory process in the papilla or in the optic nerve, and in those in which there was a slight round cell perivascular infiltration this was evidently a secondary process.

Further, the degenerative and atrophic changes that occur in the nerve-fibres and ganglion cells can be best explained as secondary to the œdema.

We therefore conclude that "optic neuritis," or "choked discs," as it occurs in association with conditions of increased intracranial pressure, is in its essential nature an *œdema*.

THE CORRELATION OF THE OPHTHALMOSCOPIC APPEARANCES AND THE HISTOLOGICAL CHANGES.

As with one exception the fifty eyes we examined were observed ophthalmoscopically during life, and many of them repeatedly, we can with some assurance attempt to correlate the ophthalmoscopic features of papillœdema with their underlying histological changes.

The hyperæmia of the discs in the early stages is evidently due to congestion of the smaller veins and capillaries in the disc itself and in the anterior layers of the lamina cribrosa. The blurring of the edges of the disc and their subsequent obscuration, as well as the burying of the vessels in part of their course, is partly a result of the increased depth of the tissue, and partly due to the dispersion of light by the œdematous fluid in the tissue, just as opacity of the lens is produced by separation of its fibres by drops of fluid. The tortuosity of the veins is mainly due to their congestion, but the swelling displaces the vessels in a plane vertical to the retina and so increases the apparent waviness of their course.

The fine greyish-white striate appearance of the disc and the neighbouring retina, especially along the vessels above and below the disc, is due to a separation of the nerve-fibres by œdema.

The striate or flame-shaped hæmorrhages are those that lie in the nerve-fibre layer and spread along the fibres; while the conspicuous "blot hæmorrhages" that occur, especially on the slope of the swelling, lie under the membrana limitans interna and separate it from the nerve-fibre layer. The less conspicuous rounded hæmorrhages lie in the deeper retinal layers, especially in the outer molecular layer.

The soft white patches of irregular shape on and in the neighbourhood of the disc, and the white stippling of the disc, are produced by the swelling of the nerve-fibres, the formation of cytoid bodies, and their fatty and other degeneration products.

The greyish-white lines that run concentric with the outer edge of the disc are obviously due to the retinal folds, their presence being occasionally accentuated by hæmorrhages lying within them.

In severe cases the retina on the macular side of the disc is swollen and greyish, owing to its œdema.

Occasionally the difference in level between the retina on the inner and the outer sides of the macula may amount to three dioptres. The faint greyish striation radiating from the macula that may be seen in these cases is due to the œdematous separation of the nerve-fibres, while the macular fan of bright white discrete spots that often develops later is due to the superficial vesicles which are formed by the raising of the membrana limitans interna from the nerve-fibre layer. As we have seen, the distribution of these is determined by the short course of the macular fibres and their anatomical arrangement. As the papillœdema subsides the macular fan may disappear and leave not a trace behind.

The opaque white appearance of the atrophic disc is produced by the diminution of the vascular engorgement, the occlusion of the smaller vessels, and the glial and connective tissue sclerosis. The shrinking of the sclerosing tissues pulls back the retina into position, and the only sign of its displacement left may be some disturbance of the pigment round the disc. The white lines along the larger veins in the neighbourhood of the disc are due to the thickening of their walls, and the diminution in the size of the arteries is brought about by their compression in the sclerosed tissues.

COMPARISON OF TUMOUR PAPILLŒDEMA WITH THE PATHOLOGICAL CHANGES IN SIMILAR OR ALLIED CONDITIONS.

(1) *Meningitis.*—We have examined the papillæ and optic nerves in three cases of meningitis (one tubercular and two septic), in which there were the ophthalmoscopic appearances of papillœdema. We have not included these cases among those of tumour papillœdema, as the local infective and inflammatory process might be possibly an additional factor in the pathogenesis of the condition, or might modify the characteristic histological changes and thus give rise to confusion. There was, however, no essential or even visible difference between the histological changes in these cases and in those of tumour papillœdema, and in them there was as little evidence of inflammatory changes in the papilla as in the latter group. Even though the meningeal infiltration extended to the optic sheath there was no inflammation of the enclosed nerve; this, indeed, might be expected, as even in the superficial layers of the cerebral cortex remarkably little change, apart from œdema, results from meningitis, unless the latter be very intense.

We can therefore conclude that the papillœdema that occurs with meningitis *need* not be inflammatory in origin, but may be dependent, like tumour papillœdema, on the increase of intracranial pressure.

(2) *Retrobulbar neuritis.*—Definite œdema and swelling of the papilla

and other signs analogous to those of tumour papillœdema may occur in retrobulbar neuritis, but probably only when the lesion lies near the bulb. Unfortunately we have not had the opportunity of examining such an eye, but we have studied for comparison an eye in which this condition existed without primary papilla changes.

This case, in which the retrobulbar neuritis was due to septic extension from the sphenoidal sinus, has been already referred to. The lesion lay near the foramen, and had at the time of death produced an extensive degeneration of the nerve, but the inflammatory changes had not spread into its distal portion, nor into the papilla.

This case is instructive in showing that local inflammatory lesions of the optic nerve itself *may not* give rise to a descending neuritis, a perineuritis or an inflammatory papillitis. In fact, from general experience there seems to be little tendency for inflammatory processes in the nerve to extend to the papilla unless they lie in its immediate neighbourhood.

We have also examined a case in which a basal tumour compressed the one optic nerve before its exit through the optic foramen, and produced a retrograde atrophy of the nerve-fibres and ganglion cells, and sclerosis of the nerve and disc. There was, however, no œdema, round cell infiltration, or other evidence of inflammation in the intra-orbital portion of the nerve or disc, despite the local lesion. In the other eye of this case there was typical papillœdema; it is included among our cases.

(3) *Albuminuric neuro-retinitis.*—There is usually little difficulty in distinguishing ophthalmoscopically between neuro-retinitis of renal or other origin and tumour papillœdema, but occasionally it is not easy to do so. It is consequently interesting to compare the pathological changes in the two conditions.

We have examined three eyes from cases of Bright's disease in which there was marked ocular change. There was no papillœdema in either eye of one case, but in the other the disc subsequently examined was swollen to the height of five dioptres.

An affection of the retina was the most prominent histological feature in all three eyes.

In two of these eyes in the nerve-fibre layer there were large areas of swollen and degenerated fibres, many over a disc-breadth in diameter, and often so close together as to be almost continuous; in many the layer was swollen to double its normal thickness. These areas were made up of varicose nerve-fibres and cytoid bodies in various stages of development, and often contained fatty or calcareous degeneration products, and in some cases the traces of older hæmorrhages. The membrana limitans interna was usually raised from their surface, and in some of the smaller foci from which the degeneration products had disappeared it formed the roof of a cavity which was crossed only by the fibres of Müller. The ganglion cell layer and even the inner molecular and nuclear layers were often destroyed below these areas of nerve-fibre degeneration.

In other places the ganglion cells were diminished in number and replaced by rows of proliferating neuroglial cells which had often a considerable quantity of cytoplasm. The inner molecular and inner nuclear layers, apart from the areas of destruction mentioned above, did not show much obvious change, except a little vacuolation of the inner nuclear layer in the vicinity of the disc. The outer molecular layer, on the other hand, was the site of very extensive change. Its fibres were pushed apart and had left large vacuoles, in many of which lay shrunken coagula; others were filled in by a reticulum of fine fibrils, and in some there were the remains of old hæmorrhages. This layer also contained large globular cells with small nuclei and granular protoplasm, which were obviously macrophages. The outer nuclear layer did not present much alteration except where the œdema from the outer molecular layer had spread into it, or where the subretinal exudate had burst through the rod and cone layer. The rods and cones were fairly well preserved on the inner side of the disc and also on the outer side beyond the macula, but in the neighbourhood of the macula where there was much subretinal exudate they were completely disintegrated, and the membrana limitans externa was destroyed. The layer contained numerous corpora amylacea. The pigment layer was on the whole normal. The adventitia of the vessels was thickened and hyaline, and the intima, especially in the smaller vessels, had proliferated so much that in many the lumen was completely obliterated.

The changes were quite as prominent in the choroidal vessels as those in the retinal, the arterial walls were specially thickened, the adventitia more than the intima. The choroid as a whole was diminished in thickness.

In the eye in which the disc was swollen the papillary changes differed in some respects from those seen in tumour papillœdema. The separation of the fibres of the lamina cribrosa was not so great, and the bulging forwards of its anterior layers was consequently only slight. The swelling mainly affected the nerve-bundles in front of the lamina cribrosa. The retina on either side was very much folded, and the space under the folds was filled with exudate. The walls of the vessels in the nerve were thickened, and either the central artery or a large branch was thrombosed. This thrombosed vessel could be traced from outside the nerve-sheath into the centre of the nerve. The general retinal changes were similar, but the patches of swollen nerve-fibres and cytoid bodies were much smaller and more scattered.

The results of our examination of these cases support the view that the retinal changes in Bright's disease are due to the direct action of the toxins on the walls of the vessels, and especially on the capillaries. The fact that the outer molecular layer, in which Müller originally showed that the terminal anastomosis of the capillaries occurs, was the most severely affected is a strong point in favour of this hypothesis.

(4) *Arteriosclerosis.*—In the course of our investigation into the nature of the changes in the nerve-fibre layer, we had occasion to cut sections of two eyes in which there was marked retinal arterial degeneration.

In the one case, though there were marked silver wire arteries, there was no evidence of complete blockage in any of them. On section the arteries showed intimal proliferation with thickening of the media. There was no pathological change in the disc itself, but along the thickened vessels which stood out conspicuously on the retina there were patches of cytoid degeneration of the nerve-fibre layer.

In the second case the upper artery was completely blocked and was represented ophthalmoscopically by branching white streaks running into a large whitish area. There was marked sclerosis of all the other vessels, and numerous patches of œdema and degeneration in the retina, with a star-shaped figure at the macula. Practically the whole nerve-fibre layer in the area supplied by the thrombosed vessel was degenerated and thickened to at least three times the normal. The thickened areas contained cytoid bodies in all stages of formation with fatty and calcareous degenerative products. Over them the membrana limitans interna was raised by exudate, only remaining attached at a few spots. In other places it was normal in position. In the affected areas of the retina the outer molecular layer contained large vacuoles, many with shrunken coagula and others with remains of old hæmorrhages. The choroid underlying the affected area was very much thicker than normal, owing mainly to the great distension of its veins, while the only change in the arteries was a thickening of their walls.

This great choroidal distension was not present under the unaffected parts of the retina.

These arteriosclerotic cases thus are quite closely allied to the albuminuric cases in their histological features, as they are ophthalmoscopically.

From the histological description it will be seen that renal and arteriosclerotic retinitis differ in their most essential features from tumour papillœdema. In the one class there is essentially a simple œdema of the papilla, and the retina is involved only to a slight extent; in the other the retina is obviously the part principally and most seriously affected.

THE PATHOGENESIS OF PAPILLŒDEMA.

It is not our intention to review in detail all the hypotheses that have been brought forward from the time of von Graefe to explain the occurrence of papillœdema in association with cerebral tumours. Some of them are based on assumptions which further investigations have proved to be far from justifiable; others are inconsistent with the facts which histological examination reveals. It is, however, essential to our purpose to refer briefly to some of the more important, and to discuss more fully the explanation which seems to us most consistent with all the clinical and histological features of the condition.

The hypotheses of previous writers may be conveniently divided into four groups:—

(1) Those that regard papillœdema as an inflammatory process (Leber [33], Gowers [18], Lawford and Edmunds [32], Deutschmann [10], Elschnig [15], Szimemi [59], and others).

(2) Those that assume that it is due to œdema propagated from the brain, in which it originally resulted from the presence of a tumour (Parinaud [46], Uhlrich [61], Sourdille [58], Kampherstein [31]).

(3) The hypotheses that attribute the swelling of the disc to a disturbance of the vasomotor innervation of the retinal vessels (Hughlings Jackson [28], Benedict [5], Adamkiewicz [1], and Loring [38]).

(4) The mechanical theories that regard the rise in intracranial pressure as the main factor.

(*a*) The original Schmidt-Rimpler [54] theory of direct driving of cerebrospinal fluid into the lamina cribrosa.

(*b*) That the disc changes are due to compression of the vessels as they pass through the lamina cribrosa or nerve (Manz [39], and Cushing and Bordley [8]); or as they pass through the vaginal space or the dural sheath (Deyl [12], Dupuy-Dutemps [13], Merz [45]); or as the result of local vascular engorgement (von Graefe's original theory [23], and Judeich [30]).

(c) That the changes are due to a lymph stasis (Liebrecht [35] and Schieck [53]).

The inflammatory hypotheses must be decided mainly on histological evidence; our own observations, as well as those of many others (*e.g.*, Kampherstein), lend them no confirmation, as in the majority of our cases there were no inflammatory changes, and in the small percentage in which there was any evidence of inflammation it was slight in degree, irregular in distribution, and obviously secondary to some pre-existing change. Further, these inflammatory hypotheses are built on unproven assumptions, as the existence of toxins derived from a cerebral tumour (Leber and his school); or a descending neuritis or perineuritis of which no satisfactory evidence has been furnished, since the occurrence of inflammation even near a tumour is exceptional, apart perhaps from the infective granulomata.

The occurrence of a descending œdema spreading from the brain lacks proof, and no very satisfactory histological demonstration of its presence has been given. It is *a priori* improbable that œdema would spread over the long tract that must be traversed before it reaches the eye. Further, it is based on the assumption that a widespread œdema occurs in the brain when this contains a tumour, but long experience of pathological investigation of brain tumours has convinced us that such œdema occurs only in the immediate neighbourhood of a tumour, and is even here relatively rare.

According to Sourdille's hypothesis, fluid is forced from the third ventricle over the chiasma and thence into the optic nerves, which are therefore, owing to their swelling, strangulated in the foramina; as a result, venous and lymph stasis in the papilla and nerve ensues.

For the vasomotor theory there has been adduced neither experimental nor pathological support. Even if a vasomotor innervation of the retinal vessels exists, it is extremely improbable, no matter what its central connexion may be, that tumours, situated as they may be in any region of the brain, could disturb its functions so seriously as to produce an œdema of vascular origin.

Our observations establish the fact that papillœdema is an œdema of the nerve-head due to two factors—venous engorgement, and lymph stasis. To understand the cause of the vascular obstruction to which this venous engorgement must be due it is necessary to review the circulation of the blood and lymph in the optic nerve and retina, and the principles that determine and modify it. For various reasons this problem must be approached from its physiological rather than from its histological aspect.

The blood of the retinal circulation is drained by the vena centralis, the branches of which unite in the papilla and pass as a single trunk through the lamina cribrosa; here it has a limited anastomosis with the choroidal veins, and with the subpial veins of the nerve-stem, though probably no anastomotic connexion with the scleral veins corresponding to the circulus arteriosus of Zinn (Leber) [34]. Behind the lamina the vein runs enclosed with the artery in a thick connective tissue sheath in the centre of the nerve. At a variable distance behind the bulb it bends out towards the pial sheath, and receives here tributaries from the pial veins. Occasionally it runs round the nerve under the pial sheath and then backwards for some distance in it: it then crosses the space of the sheath, unsupported, to reach the dura mater, which it penetrates more or less obliquely. In the orbit it usually joins one of the ophthalmic veins, generally the lower, and through them, or directly, enters the cavernous sinus. Through them, too, it communicates with the facial vein and with the pterygoid plexus.

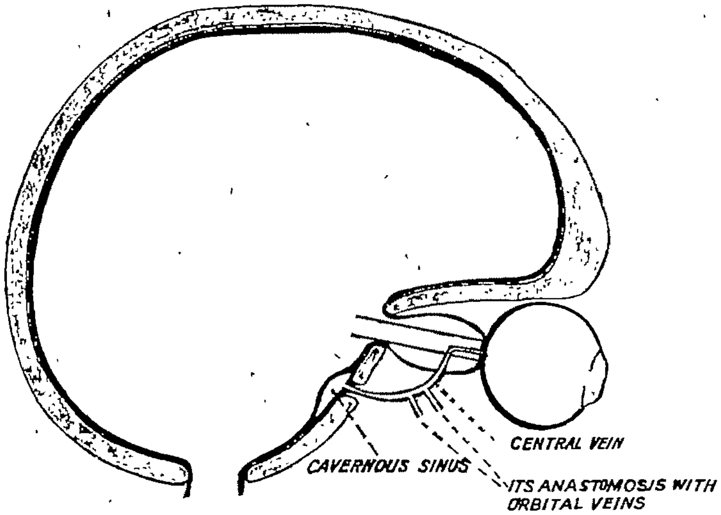

FIG. 21.

Diagram of connexions of central vein.

The conditions under which the flow of blood takes place in the optic nerve are those which Leonard Hill [25] has shown to exist in the intracranial circulation. This must be so, for, as Schwalbe [57] has shown, there is a free communication between the nerve-sheath and the cranial cavity, and unless this is blocked pressure must be transmitted from the one to the other by the cerebrospinal fluid.

The normal intracranial pressure is determined by the venous pressure, and in pathological conditions can never exceed it, else the veins would collapse owing to the little resistance their walls can offer to compression. Similarly the blood-pressure in the cranial sinuses must rise parallel with the rise of intracranial pressure; the cavernous sinus is no exception, for though it may not be readily compressible owing to the support it receives from the recess in which it lies and the firm trabeculæ that traverse it, the pressure of blood within it must equal that of the petrosal sinuses into which it drains. An increase of the intracavernous pressure seems, however, to have little direct influence on that of the central retinal vein. V. Graefe, who originally suggested engorgement of the central vein, due to rise of the cavernous pressure, as the cause of papillœdema, abandoned it when Sesemann demonstrated its free communication with the facial vein and the pterygoid plexus. But a stronger argument against this view is the fact that ophthalmoscopic changes occur in only a small proportion of cases of thrombosis of the cavernous sinus, and probably only in those in which the thrombus extends to the ophthalmic anastomosing branches (Uhthoff). It must therefore be concluded that the pressure of the vena centralis need not rise parallel with, or even in conjunction with, a rise of the cavernous sinus pressure.

It thus appears that the venous pressure in the retina and optic nerve is not *directly* dependent on the intracranial venous pressure, and may be little, if at all, influenced by it. But the intravaginal pressure rises parallel with the intracranial pressure, as there is a free communication between their spaces, and if the former is increased the pressure in the central vein must, by the same law that determines the cerebral venous pressure, rise to, or above, the same level if circulation is to be maintained within it. In its intraneural course the nerve, with its strong connective tissue septa, may prevent the sheath tension acting fully on the vein, but its intravaginal portion must depend almost entirely on its inside pressure to maintain its lumen; consequently here, at least, the venous pressure must equal that transmitted to the sheath from the cranial cavity. This rise of intravenous pressure must extend to all the distal portions of the vein and its branches, as well as to the pial veins that drain into it, and all these must consequently become congested.

The pressure in the central vein of the nerve and in the pial veins cannot differ widely from the tension of the tissues in which they lie, as the latter, too, are subjected to the increased intravaginal pressure. But the effects of this cannot extend beyond the lamina cribrosa; therefore, as the pressure in the retinal veins and capillaries must rise parallel with that of the central vein, and as there is no increase of intra-ocular tension there arises a disproportion between the capillary and venous tension and the tissue lymph tension in the papilla. Under these conditions there must occur a venous engorgement which leads to an excessive lymph transudation. If the lymph drainage were unobstructed a permanent œdema of the tissue would not necessarily result, as the outflow might readily accommodate itself to the increased production. In cases of thrombosis of the central vein, for example, whether complete or partial, there is obstruction to the venous return, and consequently venous congestion, but as there is no obstruction of the lymph drainage there is little or no swelling of the disc. In this case we have the venous congestion acting without the second factor. But the lymph from the disc and nerve normally drains into the subarachnoid space of the sheath along the adventitial coats of the central vessels, and in the case of the nerve along the vessels that penetrate it from the pia mater; consequently any rise of sheath pressure must obstruct this outflow, and actually dam the lymph back until its pressure reaches the level of the intravaginal pressure. As the retina and optic nerve, like the rest of the central nervous system, have no proper lymph vessels, the tissues into which the lymph is transuded must distend until the pressure exerted in the stretching of them comes to equal that which obstructs the drainage of the lymph from them. When this point is reached a balance is established which will be maintained until an alteration takes place in one or other of the two forces; either the pressure in the sheath may be lowered (by trephining or when the communication with the intracranial cavity is cut off), or the development and contraction of cicatricial tissue in the disc may increase the power of the tissues to oppose distension. Even if the retinal lymph drain along the optic nerve directly into the intracranial cavity the same result must ensue, as the same raised pressure must block the outflow.

In our opinion therefore, the œdema of the papilla that constitutes tumour papillœdema is in the first place due to the venous engorgement that results from the rise of intravenous pressure that is necessary in *order that circulation should be maintained in the intravaginal portion of the vein where this is subjected to an increased sheath pressure. The increased sheath pressure is also the origin of the second factor, the obstruction to the lymph drainage from the papilla.*

In other conditions, as orbital tumours and thrombosis of the cavernous sinus, a blocking of the venous return may be in itself sufficient to produce papillœdema, but as we have already shown, it does not necessarily do so.

It may be advanced as an argument against this theory, that cases of papillœdema have been described in which *post-mortem* examination revealed no dilatation of the dural sheath; the inference might be drawn that in these cases the intracranial pressure was not transmitted to the sheath. But such observations may be fallacious, as the cerebrospinal fluid can escape readily after death, especially when the body lies on its back. Even in the cranium there is often no *post-mortem* evidence of an increased pressure that undoubtedly existed during life; and this is especially so when the examination is conducted a considerable time after death. Further, though the intravaginal pressure be raised, it need not necessarily distend a strong dural sheath.

Any pathogenic hypothesis must take cognizance of the cases in which papillœdema does not appear in one eye, or if already present subsides, when the pathological intracranial pressure is due to a tumour growing in the neighbourhood of the corresponding optic foramen. We have ourselves seen three such cases in which there was intense papillœdema in the eye of the side opposite to the tumour, but no disc swelling in the eye of the same side; and others have been recorded (Gowers [20], Schultz-Zehden [56], Judeich [30]). A tumour in this region may, directly or indirectly, block the communication between the intracranial cavity and the nerve-sheath, so that the increase of pressure in the former cannot be transmitted to the latter; our hypothesis demands that, as actually does occur, in these conditions papillœdema should not develop in the eye.

We can now consider the several other theories that are based on the assumption that a raised intracranial pressure is the primary causal factor of papillœdema. The majority of these assume an obstruction to the return of blood or lymph from the papilla, and seek to explain it.

Judeich [30] modified von Graefe's original theory with which we have already dealt. His own observation was made on a single case of septic thrombosis of the cavernous sinus. He assumes that the increased pressure of the cavernous sinus is propagated through the central retinal vein to the veins of the nerve-sheath, which consequently become congested; a hydrops of the sheath results, and this causes a further pressure on the central vein. But, as von Graefe himself recognized, the pressure of the central vein need not rise parallel with that of the sinus, owing to its free anastomoses in the orbit. And the intravaginal pressure that would result from such transudation of fluid into it could not rise above that of the congested veins, and could therefore not compress the central vein.

According to Schmidt-Rimpler's [54] original theory, the raised intracranial pressure drives the cerebrospinal fluid into the vaginal space and thence into the lamina cribrosa, where it produces a compression of the nerve-fibres, a papillary œdema, and a secondary venous congestion. Manz [39] modified this view; he excluded penetration of fluid into the lamina, but assumed a direct compression of the vessels in the nerve at their entry into the lamina cribrosa by the increased sheath pressure to which they are subjected.

The main objection to these hypotheses is that no evidence of compression of the vein in the axis of the nerve has been satisfactorily demonstrated; it was certainly not present in our cases, on the contrary the vein was usually congested and engorged (fig. 10). Further, if the increased sheath pressure compress the vein, it is more likely to do so in its unsupported part as it crosses the sheath, than where it is supported by the surrounding nerve. The passage of fluid from the sheath, as Schmidt-Rimpler originally suggested, is very improbable, as the tissue tension must rise parallel with that of the veins, which must always, if circulation continue, exceed that of the compressing fluid.

Schieck [53] in a recent monograph advances the view that the increased sheath pressure obstructs the lymph drainage along the axial strand of the central vessels, from the papilla and vitreous and may even drive the sheath fluid into the lymph spaces of the nerve. Thus œdema and swelling of the disc are produced, and by pressure on the central vessels a secondary venous engorgement. This hypothesis loses sight of the fact that the intravenous pressure must exceed the sheath pressure, and, consequently, a pressure transmitted from this to the lymph in the tissues cannot compress the vein. Further, if there were the free lymph communication which he assumes between the vitreous and the papilla, the œdematous fluid in the latter would escape into the vitreous, and so drain away through the anterior chamber, without swelling of the disc necessarily resulting.

Saenger's [52] views have not yet been published in detail, but as far as we can gather from a short abstract of his recent address, he believes that the sheath is first distended by cerebrospinal fluid, but as the intracranial pressure rises the optic nerve is compressed, and the communication of its sheath with the intracranial cavity is cut off by the pressure of the frontal lobe from above and the temporal lobe from the outer side on the dural fold that surrounds the nerve at its entry into the canal. In this way the flow of lymph in the nerve is obstructed and a papillœdema results. In the circumstances it would be unfair to criticize this hypothesis in detail, but we must again draw attention to the fact that tumours which lie in the neighbourhood of one optic foramen or compress one optic nerve from above may arrest or prevent the development of papillœdema in the corresponding eye, and when the tumour invades this neighbourhood after neuritis has appeared, it may cause a rapid subsidence of the swelling and induce a pressure atrophy. Further, it is a well-ascertained clinical fact that even moderate pressure on the nerve interferes first with the function of the macular fibres, and thus gives rise to a central scotoma, which is exceedingly rare in papillœdema.

Behr [4] has adopted a similar explanation from his study of a case of oxycephaly, but he assumes, in addition to compression of the nerve in its foramen that the lymph stasis that results from this compresses the vein in the nerve and thus produces the venous congestion and engorgement in the fundus. But as lymph is secreted only at capillary or venous pressure its tension can never rise sufficiently high in the tissues to interfere with the venous circulation.

Though it is impossible to accept compression of the nerve in its foramen, as assumed by Saenger and Behr, as the cause of papillœdema, we think this may be an important factor in cutting short the course of a papillœdema (as it must, if our hypothesis be correct) and in producing a secondary atrophy which may be indistinguishable ophthalmoscopically from a primary atrophy.

According to Deyl's [12] hypothesis the site of venous obstruction is in the dural sheath. The displacement of this by distension of the space produces an acute bending and compression of the vein as it enters the dura and so obstructs the venous outflow. But, like Elschnig [16] and others, we failed to find any anatomical evidence of this compression of the vein in the dura or of the engorgement he describes in the portion that crosses the space. Dupuy-Dutemps [13] originally supported Deyl, but in his later paper [14] he regards it as more probable that the compression takes place in the space or under the pia

Henderson [24], in his recent book on "Glaucoma," suggested on *a priori* grounds that papillœdema is due to the difference between the pathologically raised intravenous tension and the normal intra-ocular tension.

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PROGRESSIVE SPINAL MUSCULAR ATROPHY OF INFANTS AND YOUNG CHILDREN.

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INTRODUCTION.

THE occurrence of progressive paralysis and muscular atrophy due to a lesion of the lower motor neuron is a condition of some rarity both in infants and young children. During the past ten years I have seen some eight cases which may be placed under such a heading. Some of these have been under my own care, others under the care of my colleagues, but I have made the pathological examination in all cases in which an autopsy has been obtainable. Some of these cases have already been published. It is from a consideration of these cases that I propose to deal with the somewhat difficult problem of progressive spinal muscular atrophy of infants and young children. It will be well in the first place to mention certain classes of cases, which though they may show progressive muscular atrophy dependent or independent of spinal disease, it is not intended to deal with in this paper. Into this category are placed: (1) The primary muscular atrophies (myopathies) and with these I include the condition known as "myatonia congenita"; (2) the effects of acute poliomyelitis; (3) spinal or spinal root injury; (4) congenital defects of the cord; (5) the peroneal type of muscular atrophy (Charcot-Marie-Tooth); (6) von Recklinghausen's disease; (7) the effects of spinal caries and spinal growth.

The eight cases on which this paper is based may be arranged in three classes; each class will be dealt with in a separate chapter. A short statement of the clinical and pathological features of the cases belonging to each class will be found at the beginning of the chapter; but for a full clinical report and details of pathological examination reference should be made to the appendix for those cases not already published, and to the article referred to for those which have been published.

Of the eight cases *six* belong to the first class, *one* to the second class, and *one* to the third class. The characters of these three classes may be stated as follows:—

(1) A type of case in which progressive muscular weakness occurs during the first weeks or months of life, gradually progresses, and terminates in death after a variable period of weeks, months, or years. Sometimes more than one member of the family may be affected. Atrophy of the cells of the anterior horn is the constant pathological change found in such cases, but it may be associated with other changes in the central nervous system (Werdnig-Hoffmann type).

(2) A type of case in which progressive muscular weakness and atrophy begins somewhat later in life, after the child has already walked, and slowly progresses till death occurs from respiratory failure or pneumonia. The pathological changes found in such cases is a degeneration of the lower motor and sensory neurons resembling those occurring in a "toxic neuritis."

(3) A type of case in which progressive muscular weakness and atrophy begins in later life after the child has already walked, slowly progresses, and is attended by very marked degeneration of the spinal cord, not limited to any one group of cells or tracts (a "myelitis").

CHAPTER I.—WERDNIG-HOFFMANN TYPE.

The cases which belong to this type are six in number, and the following is a short abstract of the clinical features and pathological changes in those cases in which a *post-mortem* was obtained:—

Case 1.—Charles H., aged 4 weeks. First child of healthy parents; no miscarriages. Said by the mother to be healthy at birth. Took breast well for fourteen days; then fed on goat's milk. Wasting and weakness of the limbs noted when 14 days old; got tired when sucking. The child never cried well.

On admission to hospital, small child, 5½ lb., feeble cry. A complete flaccid paralysis of arms and legs, with slight movements of fingers and toes, neck muscles flaccid. Sucks well, no regurgitation; deep reflexes absent, sensation apparently normal, no reaction obtained in muscles by strong faradic current. Death after three days.

Post-mortem.—Nothing abnormal to naked eye in visceral or nervous system. No evidence of birth injury. Microscopical examination: Marked degeneration of anterior nerve-roots throughout the cord; some chromatolysis of anterior horn cells; no evidence of muscular degeneration. (See figs. 1, 2, 3, 4, 5, 6.) (See Appendix.)

Case 2.—William G., aged 5 weeks. The eighth of eight children, three of whom have died of a similar complaint within the first few months of life. The labour was difficult. On admission to hospital the child was well nourished, looked healthy, and took food well. There was complete flaccid paralysis of all four limbs, except for slight movements of the fingers. There

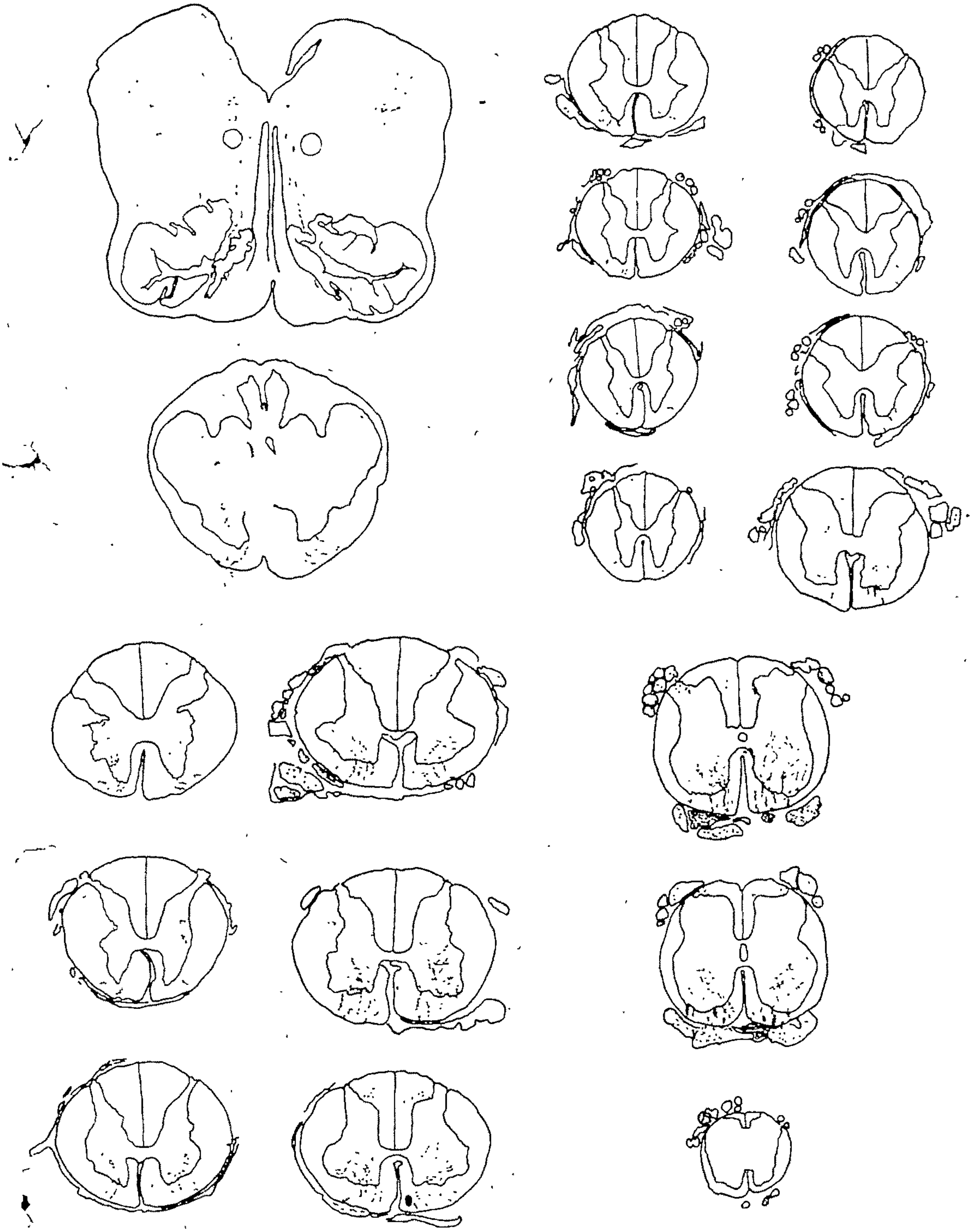

FIG. 1.—Series of section through the spinal cord, from the Case 1, Charles H., stained by the Marchi method, showing the degeneration of the anterior root.

The stress of the disease is seen to fall on the lumbar and the cervical region of the spinal cord, but some degeneration is present throughout the whole length of the cord and medulla.

was complete paralysis of the trunk muscles and intercostals, but the diaphragm acted well. All the deep reflexes were absent; there was analgesia below the second rib. The child died when 8 weeks old of broncho-pneumonia.

Post-mortem.—Nothing abnormal on macroscopical examination; but on microscopical examination widespread atrophy of the cells of the anterior horn, and degeneration of the fibres of the posterior column. (See figs. 7 and 8.) (See BRAIN, 1902, xxv, 85.)

Case 3.—Edward T., aged 4 months. Fourth of four children, one of whom was said to have died of a similar complaint. Easy labour. General helplessness noticed one week after birth; gradually increased. On admission, flaccid paralysis of arms and legs, absence of deep reflexes, paralysis of intercostals. Death. No *post-mortem.* (See Appendix.)

Case 4.—Percy B., aged 6 months. Fourth of four children. Full term; normal labour. Healthy at birth. Gradual onset of weakness first noticed in the arms when 4 months old. Well nourished, intelligent child. Flaccid paralysis of arms, legs, trunk, neck. Paralysis of intercostals. Absent reflexes. Sensation apparently normal. Death. No *post-mortem.* (See Appendix.)

Case 5.—Henry C., aged 8 months. Third of three children, others healthy. Breast-fed. Normal labour. Always weak; never able to sit up or hold its head up. Weakness has increased.

There was flaccid paralysis of both arms, and both legs. Weakness of back muscles with lateral curvature of the spine. Knee-jerks only obtainable with difficulty.

Death after four days in hospital.

Post-mortem.—Nothing abnormal on macroscopical examination. On microscopical examination some degeneration of the anterior roots and some chromatolysis and atrophy of the cells of the anterior horn. (See Appendix.)

Case 6.—Ronald A., aged 3½ years, one of twins. Never learnt to sit up. Learnt to talk early. When 15 months old could not move his legs, but could move the arms.

When first seen in June, 1910, he was quite intelligent, had flaccid paralysis of both legs, was quite unable to sit up or maintain a sitting position; he could, however, hold up his head. Sensation was perfect. The knee-jerks were absent. The intercostals paralysed. He died from broncho-pneumonia in September, 1910.

Post-mortem.—Broncho-pneumonia. Microscopical examination showed smallness of anterior nerve-roots of the spinal cord, and marked atrophy of the cells of the anterior horns. No Marchi degeneration. No vascular change. (See figs. 9 and 10.) (See Appendix.)

CLINICAL FEATURES OF CLASS 1.

An infant born at full term and apparently normal at birth begins in the first few weeks of life to show weakness of the trunk and limbs. The infant appears of normal intelligence. The weakness steadily

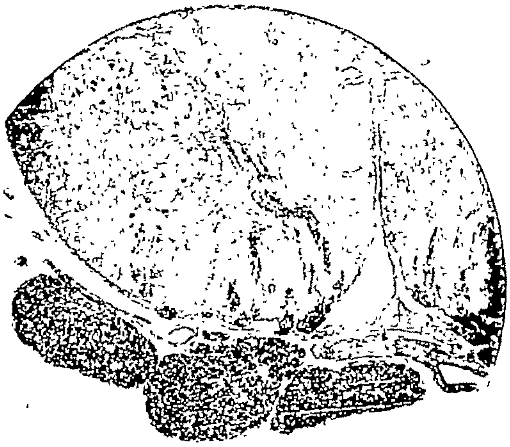

FIG. 2.—Photograph of the anterior region of the sacral cord from Case 1, Charles H., showing the degeneration of the anterior nerve-roots in their intramedullary course. Stained by the Marchi method.

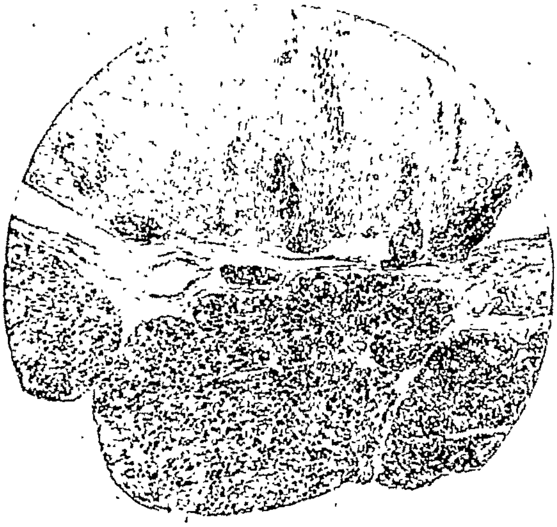

FIG. 3.—Photograph of anterior roots showing degeneration of the anterior roots in their extramedullary course. Stained by the Marchi method.

progresses, so that there is a complete flaccid paralysis of both arms and legs, and only a little movement is preserved in the fingers and toes. The intercostal muscles become paralysed and the child dies from some intercurrent disease, generally of broncho-pneumonia. Several members of a family may in succession be affected, as in the Case 2, where four children out of a family of eight were thus affected. In Case 3, another member of the family is said to have died from the same disease.

The clinical picture which these infants present is very striking: The infant lies in bed, happy and contented, taking his food well, but completely unable to move either arms or legs, the limbs being perfectly flaccid. The disease tends to affect the proximal muscles before the distal, so that all movements of the fingers and toes are still possible after power has been lost in the shoulders and hips. If an attempt is made to lift up the child the extreme flaccidity of the trunk muscles is easily recognized. The actual wasting of muscles in some cases is not obvious, for it is covered up by the subcutaneous fat. The child will, as a rule, rapidly respond by crying when pricked by a pin, and as far as can be judged, sensation is perfect. All the tendon reflexes are either

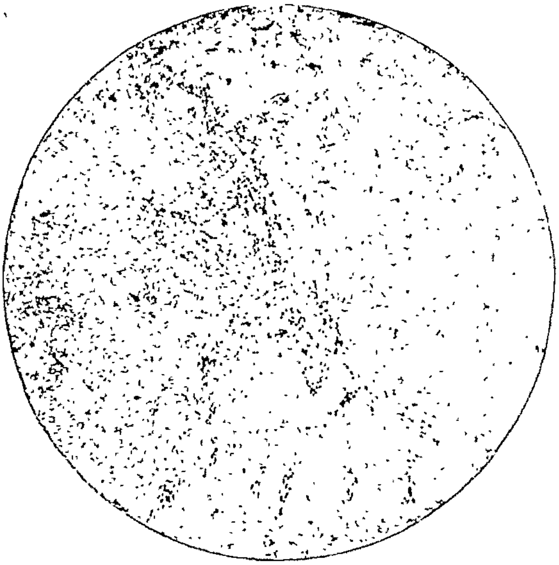

FIG. 4.—Photograph of grey matter, showing degeneration of fine fibres arising from cells of anterior horns. Stained by the Marchi method.

absent or greatly diminished. In those cases in which the electrical reactions have been examined the absence or great diminution of excitability to the faradic current is a most striking feature. The duration of life in most of these cases is limited by months, but in one case of the present series the duration of life was considerably longer, viz., three and a half years.

PATHOLOGICAL FEATURES OF CLASS 1.

The clinical features of the disease are fairly constant. The pathological features differ somewhat. These differences may depend upon the length of time the disease exists before a fatal issue ensues; for that issue, although dependent in part on the progress of the disease, and especially on the paralysis of the intercostal muscles, yet it is often accelerated by the occurrence of broncho-pneumonia.

In four of the six cases belonging to this class a pathological examination was made, viz., Cases 1, 2, 5, 6.

In Case 1 there is the most marked degeneration of the medullary sheath of the fibres of the anterior roots of the spinal cord from their origin in the cells of the anterior horns, in their intramedullary course through the cord, and in their extramedullary course. (Figs. 1, 2, 3, 4.) This degeneration is most strikingly shown by the Marchi method. The peripheral nerves show but little change. The cells of the anterior horns show but little change, when considered in relation to the marked change in the fibres. Some few cells undoubtedly show chromatolysis (figs. 5 and 6), but only a few compared to the numbers of fibres which are affected. (Compare figs. 1, 2, 3, 4, 5, 6.)

The muscles in Case 1 do not show any marked change, the muscle-fibres being in the condition seen in a late fœtal or infantile life.

The changes met with in Case 2 are somewhat different. In this case there is a marked atrophy of the cells of the anterior horn throughout the cord (figs. 7 and 8), without the striking degeneration of the anterior roots as shown by the Marchi method. There is some degeneration of the posterior column of the spinal cord. The muscle shows a curious mixture of atrophy and hypertrophy of muscle-fibre, but no fibrosis.

The changes met with in Case 5 are similar to those in the two former cases, but differ in the following respects, viz., that the Marchi degeneration is less marked than in Case 1, and more marked than in Case 2, while the chromatolysis is more marked than in Case 1 and less marked than in Case 2.

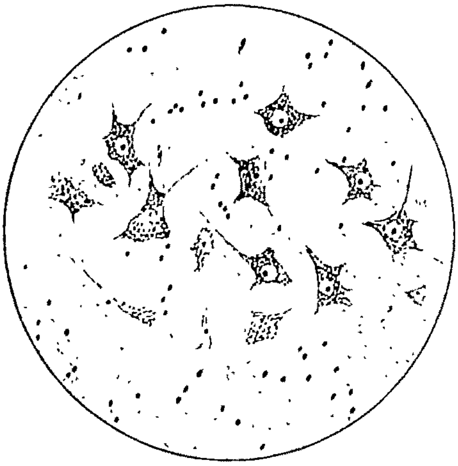

FIG. 5.—Cells of the anterior horns of cervical region, stained by the Nissl method, from Case 1, Charles H. Most of the cells appear normal, some, however, show slight chromatolysis.

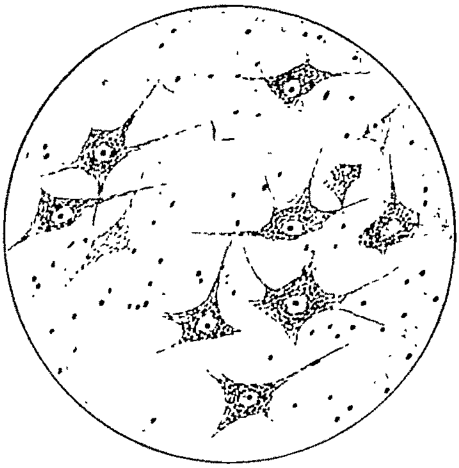

FIG. 6.—Cells of the anterior horns of the lumbar region, stained by the Nissl method, from Case 1, Charles H. The cells as a whole appear strikingly normal in appearance, considering the marked change seen by the Marchi method; some, however, show slight chromatolysis.

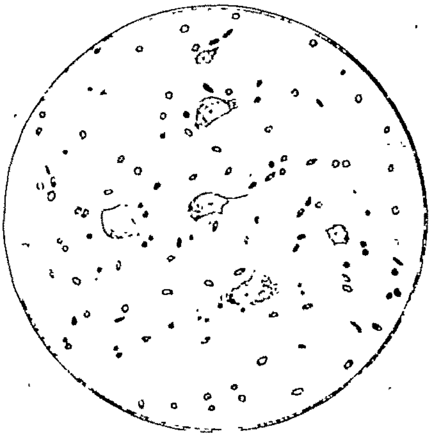

FIG. 7.—Cells from the anterior horns of the cervical region, stained by the Nissl method, from Case 2, William G., showing marked atrophy. Compare them with the normal-sized cells of fig. 5. *Drawn under same magnification*, 170 *diameters*.

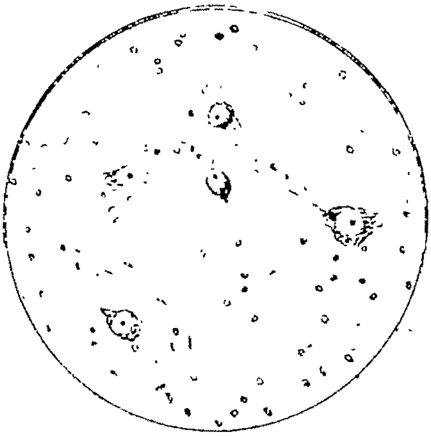

FIG. 8.—Cells from the anterior horns of lumbar region from Case 2, showing same condition.

The changes met with in Case 6 are similar to those seen in Cases 2 and 5, viz., the marked atrophy of the cells of the anterior horns, and of the anterior roots, only a few normal cells persisting. (Figs. 9 and 10.)

If the pathological findings in these four cases are carefully considered together, may not the differences be explained partly by the intensity of the poison, and partly by the duration of the disease? In Case 1 the appearance is very similar to that met with in diphtheritic paralysis, the most marked changes being visible in the medullated sheath of the nerve, whilst the cells exhibit but little chromatolysis. At a later stage the products of degeneration shown by the Marchi method become absorbed, whilst the chromatolysis and atrophy of the cells as shown by the Nissl method become more marked. Such a condition is well exemplified in Case 5, where there is a condition both of chromatolysis and atrophy of the cells, with some degeneration of the myelin sheath of the fibres, an appearance compatible with a more chronic course, dependent on a lesser dose of the toxin. The longer clinical history of this case corresponds with such a result.

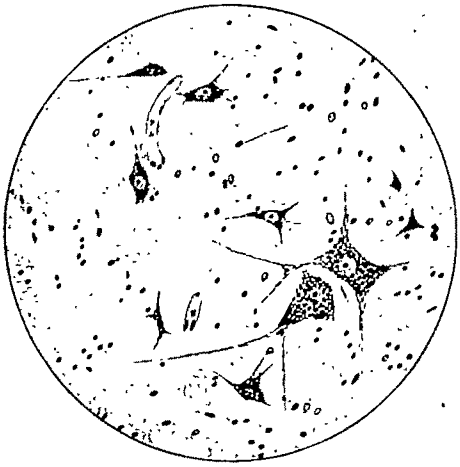

FIG. 9.—Cells from the anterior horns of the cervical region, stained by Nissl method, from Case 6, Ronald A., showing marked atrophy of cells, two normal cells alone remaining.

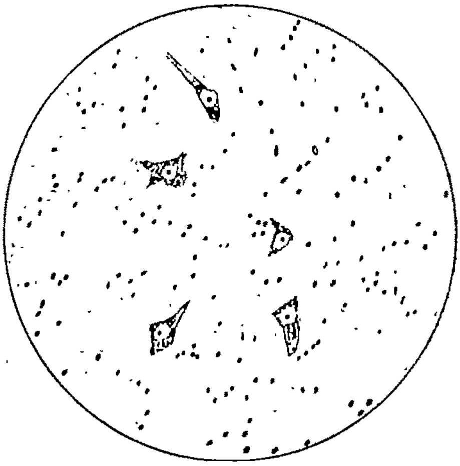

FIG. 10.—Cells from lumbar region of Case 6, showing similar changes. *Magnification* 170 *diameters*.

In Case 6, a case of three years' duration, the cells and roots have undergone atrophy, and the pathological picture represents the later stages of the disease.

The question as to the nature of the toxin to which these changes are due may be raised, but on that point there is yet no evidence. Certain poisons are known to act especially on the lower motor neurons, and as an instance of such, diphtheria, lead and arsenic may be quoted.

The changes found in Case No. 1 resemble closely those found in diphtheritic paralysis, and it might be suggested that the mother had diphtheria before the birth of the child, and the resulting degeneration was due to that poison. Lead and arsenic might similarly be thought of, but the only object of such hypotheses is that in investigating future cases, examination might be made for these poisons. On the other hand, the occurrence of the disease in families, although not absolutely excluding the toxin theory, yet renders such a view improbable, and would seem to point to the condition being due to what Sir William Gowers has termed an "abiotrophy," that is, a "degeneration dependent on a defective vital endurance."

Recently Catola has examined the nervous system of infants born of parents suffering from various diseases. The changes which he figures and describes in the cells of the anterior horns and in the anterior roots in the child of an eclamptic mother and in that of a syphilitic mother are strikingly similar to those described in Case 1 of my series.

CHAPTER II.—TOXIC NEURITIS.

Abstract of Case.

Case 7.—Hetty M., aged 3. Weakness of limbs first noticed when 3 years old; the weakness gradually progressed, but there were considerable remissions during which the child improved. Deep reflexes became abolished. Muscles of trunk, intercostals and diaphragm became involved. Death from bronchopneumonia fourteen months after onset.

Post-mortem.—No macroscopic change in nervous system. On microscopical examination chromatolysis of the cells of the anterior horns and degeneration of the peripheral nerves. Fatty degeneration of muscles. (Figs. 10 and 11.)

CLINICAL FEATURES OF CLASS 2.

The case which is placed in this class is one which was under the care of my colleague Dr. Voelcker, and was shown by him at the Medical Society, November, 1908, and February, 1909. I saw the child on various occasions. One of the most striking features of the case was, that although the disease was slowly progressive, yet there were periods during which improvement took place. The disease ran its course in a period of fourteen months.

The clinical features of this class as based on this case are as follows :—

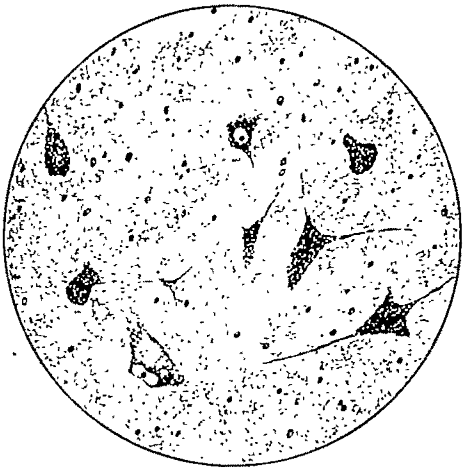

FIG. 11.—Cell from anterior horn of the cervical region from Case 7, Hetty M., showing marked chromatolytic changes. Stained by Nissl method. Magnified 170 diameters.

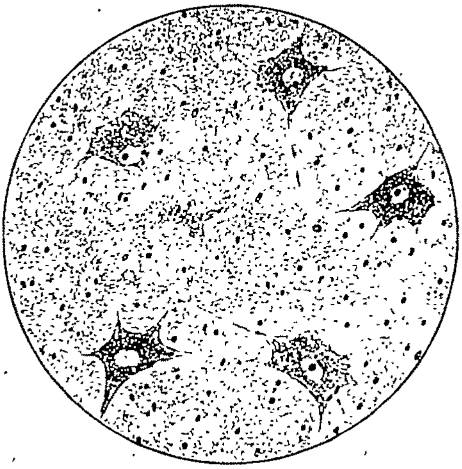

FIG. 12.—Cells from anterior horn of lumbar region, from Case 7, Hetty M., showing marked chromatolytic changes similar to those in the cervical region. Stained by Nissl method. Magnified 170 diameters.

An apparently healthy and intelligent child, who had made normal progress, without any obvious cause was noticed one morning to be unable to walk properly and to fall after taking a few steps. This weakness gradually progressed, so that the child became unable to walk and unable to feed herself. There was incontinence of urine and fæces for a time. There was a transient weakness of the muscles of the face. All the deep reflexes became abolished. The muscles showed the reaction of degeneration. The respiratory muscles became affected. Sensation was unaffected, and there was no pain.

Some improvement took place for a few months, then the disease steadily advanced and the child died some fourteen months after the first symptom.

PATHOLOGICAL FEATURES OF CLASS 2.

The brain and spinal cord to the naked eye appears quite normal, and on microscopical examination could no change be shown by the Weigert-Pal method. Some slight degeneration is seen by the Marchi method, both in the white matter of the cord and in the anterior and posterior roots. Some of the cells of the anterior horn, both in the cervical, dorsal and lumbar region show chromatolysis, others have already undergone atrophy. (Figs. 11 and 12.)

The peripheral nerves show a considerable amount of degeneration by the Marchi method. The changes appear to be more marked in the peripheral nerves than in the central nervous system.

The muscles and fibres of the diaphragm show a marked fatty degeneration by the Marchi method.

The changes found are probably the result of some toxin affecting the lower neurons (" toxic neuritis ").

This case has been classed as a " toxic neuritis," partly on clinical grounds, partly on pathological grounds. The clinical history of the case is distinct from that of the cases which form Class 1. The onset of the disease, the irregular course, the reaction of degeneration, the affections of the diaphragm, are all symptoms to which, if taken singly, no special value in the differential diagnosis could be attached, but if taken together suggest a poison acting diffusely in the lower neurons, rather than a poison which is acting primarily on the cells of the anterior horn.

On pathological grounds the extensive degeneration of the peripheral nerves as compared to the slighter changes in the cells of the anterior horns, together with the character of those changes, seem to me to be points in favour of regarding this case as one belonging to the class of " toxic neuritis."

It is admittedly one of the most difficult problems in neurology to differentiate between cases of "toxic neuritis" and those due to degeneration of the cells of the anterior horn.

On clinical grounds there is no doubt that the distinction is useful; on pathological grounds it seems to me doubtful if the distinction can be drawn between affections of various portions of the lower motor neuron, but for the present I would classify those cases which show rather diffuse changes in the peripheral nerves, and but little change in the anterior horn cells or anterior roots, as "toxic neuritis," and those cases which show marked changes in the anterior horn cells and anterior roots, and but little or scattered degeneration in the peripheral neurons, as "spinal atrophies."

The question as to the advisability of including such a case in a series of cases described as progressive spinal muscular atrophy might be raised. Few, I think, will be disposed to press this objection against the obvious advantages of considering together cases which have a marked clinical similarity.

CHAPTER III.—CHRONIC MYELITIS.

Abstract of Case.

Case 8.—Matilda L., aged 11. Twelve months' weakness of hands, four months' weakness of legs. Gradual increase of weakness and muscular atrophy. Reaction of degeneration in some muscles. Sudden death from respiratory failure eighteen months after onset of illness.

Post-mortem.—Extensive myelitis of both grey and white matter of the spinal cord, giving rise to atrophy of the cells of the anterior horns. (BRAIN, 1903, xxvi, p. 473.)

CLINICAL FEATURES OF CLASS 3.

The case on which the third class is described is one which was published in BRAIN, 1903, by Dr. Morley Fletcher and myself. It is in its clinical and pathological manifestation entirely distinct from the other two groups, and yet it possesses the characteristic feature, viz., progressive muscular atrophy of spinal origin.

The clinical features are given in the following short abstract :—

A girl, aged 11. Twelve months' weakness of hands; seven months unable to button clothes; four months' weakness of legs. Two months ago adenoids removed and much worse since that operation. Fourteen days' pain in back and increased difficulty in swallowing. Intelligent, deaf, some atrophy of tongue, palate moves well on phonation, weakness of neck, respiration thoracic, upper intercostals only in use. Claw-hand, wrist-drop, weakness of upper arm and shoulder muscles. Can walk but feebly; knee-jerks brisk, plantars flexor. Sensation natural to all forms. Electrical reaction shows R.D. in some muscles, in others only diminution of excitability.

Sudden death from respiratory failure six months later.

PATHOLOGICAL FEATURES OF CLASS 3.

There is extensive destruction and atrophy of the cells of the anterior horn from the upper cervical to the lower thoracic segments, these changes being most marked at the level of the sixth thoracic segment; the cells of Clarke's column being also affected. There is extensive degeneration of the whole of the ventral region of the cord in the thoracic segments, the lesion being most marked at the level of the sixth thoracic segment, and diminishing in extent both towards the medulla and caudally. There is extensive degeneration of the direct cerebellar tracts, both dorsal and ventral, beginning in the lower thoracic segments and extending up to their respective termination in the cerebellum. The degeneration affects both grey and white matters alike.

There is a marked increase of the connective tissue in the ventral portion of the cord. The walls of the vessels show no change. The cords shows show both recent and old degeneration. (BRAIN, 1903, xxvi, 473.)

This case must be regarded as a chronic form of diffuse myelitis, secondary to some vascular changes and toxic blood state. The origin and cause of the myelitis and of the peculiar distribution is unexplained.

CHAPTER IV.—DIAGNOSIS.

The differential diagnosis in the first class of cases above described is one of the greatest difficulties. A child who at the *time of birth* has a complete flaccid paralysis of all four extremities is probably the subject of a spinal hæmorrhage, due to traumatism at birth. The child who during the first few weeks or months of life *develops* a flaccid paralysis of all four extremities is probably the subject of a spinal atrophy; but the difficulty of differentiating these two conditions is well shown in the two cases recorded by Dr. Beevor. Two children, when a few weeks old, exhibited the same clinical picture, viz., that of a complete flaccid paralysis, and yet on pathological examination it was found that in the one case the condition was due to spinal hæmorrhage, in the other to an atrophy of the anterior horn cells. In children rather more advanced in age other questions came up for consideration, and one of the most difficult is the distinction of a primary spinal condition from a primary muscular condition or myopathy.

The forms of myopathy which occur in young children become year by year more generally recognized. The "simple atrophic" type of Erb and the condition known under the name "myatonia congenita" may easily be mistaken for the Werdnig-Hoffmann paralysis. Myatonia congenita is a disease of early childhood, characterized by an extreme degree of loss of tone and feebleness in all the muscles of the body. The condition is stated to improve as the child advances in age.

A child with this disease can, as a rule, perform all movements in a feeble manner, and there is not the marked degree of flaccid *paralysis* seen in the case of spinal atrophy. Although hypotonia is present in cases of spinal atrophy, yet it is not so marked as in cases of myatonia congenita. Again, the intercostal muscles are commonly paralysed in the spinal atrophy of infants, whereas in myatonia they are less affected.

Shortly, it may be said that in spinal atrophy the paralysis is more marked and the hypotonia less marked than in cases of myatonia congenita.

The difficulty of diagnosis is well exemplified by the three cases in one family described by Finkelnburg. These would, on clinical grounds alone, be assigned to the Werdnig-Hoffmann group, and yet on pathological examination he has shown that they belong to the myopathic group—there being no change in the spinal cord, and changes in the muscles typical of myopathy.

Spinal caries may, under certain circumstances, rather closely simulate this disease, especially when the tuberculous process has spread in through the membranes and invaded the spinal cord. Cases of widespread poliomyelitis occurring during infant life may clinically resemble Werdnig-Hoffmann paralysis, but the paralysis and atrophy of muscles is rarely symmetrical, and groups of muscles tend to be picked out, leaving others unaffected.

In the second and third class the diagnosis is no more easy than in the first group, and even with the pathological knowledge obtained from the examination of these cases, it would be most difficult to assert in cases presenting similar symptoms what was the cause of the widespread progressive muscular atrophy.

CHAPTER V.—LITERATURE.

Since the year 1898 there are only some five cases of the disease recorded, in which there has been a pathological examination. These are the cases recorded, one by Hoffmann, one by Beevor, two by von Ritter, and one by Armand-Delille and Boudet. Previous to that date there are the well-known cases of Werdnig and Hoffmann on which the clinical features and pathology of the disease are founded, to which may be added the case recorded by Thomson and Bruce, *i.e.*, ten cases, to these may be added the three cases in this paper, making thirteen cases in all.

Of cases without autopsy there are those recorded by Senator, Sevestre, Bruns, Wimmer, Haushalter, Lange. Some of these, and notably those of Bruns, Senator, Haushalter, and Lange, and the second case of Wimmers, should almost certainly be classified as myopathies and not with the Werdnig-Hoffmann group. The earlier cases of Werdnig and Hoffmann have already been reviewed in BRAIN, 1897. The later case of Hoffmann and those of Beevor, von Ritter, Armand-Delille and Boudet will be considered.

Hoffmann in 1900 recorded the result of the autopsy on the child Margarethe G., the details of whose case had already been published in 1897. The paralysis slowly progressed, only feeble movements of the hands and feet remaining till the end. The face, tongue, muscles of deglutition, remained unaffected. The higher senses were normal, and there was no affection of the bladder or rectum. Sensation remained intact. The child died when 5 years old of pneumonia. On examination of the spinal cord there was found to be atrophy of the intra- and extra-medullary portions of the anterior roots, degeneration and wasting of the multipolar ganglion cells, and degeneration of the peripheral nerves. The pyramidal tracts showed no change. There was wasting of the muscle-fibres with fatty degeneration and interstitial fat.

Beevor's case, published in 1902, is recorded in the Appendix, and is one of those included in the substance of the paper. Shortly, the leading features are as follows: An infant, the eighth of a family of eight, four of whom had been similarly affected, had flaccid paralysis of all four limbs. The child died at 2 months old, and extensive atrophy of the cells of the anterior horns was found.

Von Ritter, in 1904, described two cases. The first, a female child, 15 months old at the time of death, the only child of healthy parents, born in normal labour, and suckled till 10 months old. When

5 months old it was noticed that the child moved its legs but little, and she seemed to get weaker in the upper extremities. The child was fat, not rickety, and had a flaccid paralysis of all its limbs. The face, mental condition, sight, and hearing were quite normal. On examination, the spinal cord showed marked atrophy of the cells of the anterior horns and atrophy of the muscle-fibres, with fatty degeneration. The second case, a female child, the second of two children, the first being quite healthy. The birth was normal. During the first year of life the parents noticed nothing amiss. In the second year of life the child gradually began to develop weakness in the lower extremities, and she had, by the end of the second year, complete loss of power in the legs, and had paresis of the arms. There was marked wasting of the buttocks, standing was impossible, sitting was possible, all the visceral functions were normal, the deep reflexes were abolished. The child died when 2 years old. On pathological examination, the anterior roots of the spinal cord were found to be very wasted, and very few normal ganglion cells remained. The muscles showed atrophy of the muscle-fibres and a marked lipomatosis. The cord does not seem to have been examined by the Marchi method.

Armand-Delille and Boudet, in 1908, described the case of a child, 5 months old, the first of two healthy parents. The infant had made normal movements of the new-born during the first weeks of life, but when 2 months old weakness of the limbs was noticed. The muscles of the neck were also weak, and the head flopped to the side.

On examination there was almost complete paralysis of the four limbs and muscles of the neck. There was paralysis of the intercostal muscles. The diaphragm alone carried on respiration. The thorax was deformed. Cutaneous sensation was preserved. All the deep reflexes were abolished. There was absence of response in the muscles, both to faradic and galvanic currents. The sphincters were intact. On account of the subcutaneous fat it was impossible to feel the muscles, which were paralysed and in the course of atrophy. The child died when 5 months old. On examination of the muscle, the nuclei appeared very abundant, and the muscle-fibres markedly degenerate. Some bundles were completely replaced by connective tissue, some of the muscle-fibres preserved their striation, but most were already in a stage of advanced atrophy. A perivascular and interstitial sclerosis was present. The muscle-fibres of the diaphragm were normal. In the peripheral nerves a number of the fibres had disappeared. The anterior roots were atrophied, the posterior roots were intact. The posterior root ganglia showed no change. The white matter of the cord was normal. There was very marked atrophy of the cells of the anterior horns and of the anterior roots. The cells which were less affected showed chromatolysis. The atrophy of the cells of the anterior horn contrasts with the normal appearance of those of Clarke's column. The meninges were intact. All these cases may be accepted as examples of the disease.

The cases, without autopsy, arrange themselves in two groups—those which from their clinical symptoms may be considered as examples of the disease, and those which from their clinical symptoms, it would not seem justifiable in the absence of any pathological evidence to the contrary, to include under the Werdnig-Hoffmann group.

Group 1.—CASES WHICH, FROM THEIR CLINICAL SYMPTOMS, AND WITHOUT AN AUTOPSY, MAY BE CONSIDERED AS EXAMPLES OF THE WERDNIG-HOFFMANN TYPE.

In the first group may be placed the cases of Sevestre and Wimmer's first case, while in the latter group I should place those of Hausalter, Bruns, Senator, and Lange.

Sevestre showed the case of an infant 2½ months old, with complete flaccid paralysis of the body, only the muscles of the head, neck, and diaphragm remaining normal. The muscles of the extremities were atrophic, and they had lost their faradic irritability and gave an anodal contraction on galvanic stimulation. The thorax was deformed. Two other members of the family of six had had the same affection and had died when a few months old. In the discussion Hutinel said he had seen a similar condition in two children born in a breech presentation, and he attributed the condition to spinal hæmorrhage. In one case, however, in which an autopsy was obtained, no such hæmorrhage was present.

Wimmer's case is that of a boy, aged 16 months. The labour was normal, and no other members of the family were affected. A few months after birth difficulty in sucking was noticed. The infant was always very weak, could not raise the arms, but could move the fingers and hands. The child could move the toes, but not the legs or thighs. The neck muscles were weak. The child was not imbecile, had no enlargement of the head, and the movements of the face, eyes, and tongue were normal. The child was a cryptorchid. The deep reflexes were absent. The muscles showed altered electrical reactions. He compares it to Beevor's case and says that it most resembles that.

Group 2.—Cases which, from their Clinical Symptoms, and without an Autopsy, *should not*, in the opinion of the Writer, *be regarded* as belonging to the Werdnig-Hoffmann Type.

With regard to the second group of cases without autopsy, recorded by Haushalter, Bruns, Senator, and Lange, I am unwilling to accept any of these as cases of muscular atrophy due primarily to atrophy of the cells of the anterior horn. Haushalter, indeed, regards his cases as primarily myopathic, though described under the title "Amyotrophie primitive progressive dans l'enfance," the first being a fairly typical case of facio-scapulo humeral type, the second belonging to the simple atrophic type, and the third probably to the myatonia congenita type, though in many features this case most closely resembles the Werdnig-Hoffmann type.

Bruns records three cases from different families. In the first family two sisters had died of the same complaint. In the second family there was no other case. In the third family the two elder and one younger members were healthy. Bruns counts these as five cases, and added to the nineteen cases already published by Hoffmann, and the two cases by Werdnig, and one by Bruce, says that there are now twenty-eight recorded cases of the disease.

The first case is that of a girl, I. R., aged 10, the fourth of four children. The family history was as follows: The first child, a boy, stood and walked at 9 months. Paralysis then occurred and he died when 4 years old. The second, a girl, died from inflammation of the lungs when 3 years old. The third, a boy, normal at birth, developed well till 9 months old, began to sit up, but could not stand, the hands were unsteady. When 2½ years old he was examined. The child could just sit up, but easily fell backward. The legs could not be bent at the hips, the weakness of the quadriceps extensor was very marked. There was loss of faradic irritability in the muscles, and a very weak reaction to galvanism. The weakness gradually extended and the child died when 3 years old. There was no *post-mortem*.

The girl, I. R., developed fairly well in the first two years of life. She nearly walked at 1¾ years, after which no progress was made. She frequently fell, and her gait became progressively worse. Weakness of the arms came on at a later date. When seen in 1894 there was very marked curving of the spine, wasting and feebleness of the arms, a weakness of the legs. The paralysis was of a flaccid character. The deep reflexes were absent. The lower arm and hands were less affected than the shoulder muscles, and the toes less affected than the upper portion of the leg. Fibrillary tremors were present. There was loss of electrical excitability, but no distinct reaction of degeneration. Intelligence, sensation and sphincters were normal. In 1896 the weakness had increased and she had difficulty in holding up the head. In 1898 there was still more weakness, atrophy of the shoulder girdle and the thighs, and more wasting of the calf muscles. In 1900 she died, when 16 years old. There was no autopsy.

The second case, E. F., aged 11. Nothing is known of the family history. She had general weakness of the shoulders and hips, standing was impossible, there was a marked kyphosis, fibrillary tremor in the shoulder muscles, diminished electrical reaction, absence of the deep reflexes. She remained in this condition.

The third case, A. N., boy, aged 3; two older brothers, aged respectively 7 and 5, are healthy, as is also the sister, aged 8 months. This child walked and talked at 1 year and 3 months. When 2 years old the mother noticed gradually increasing weakness. The child lost the power of walking, developed a tremor of the hands and weakness of the back. The legs showed the greatest amount of weakness. The face, eye, muscles of the tongue were unaffected. There was fibrillary tremor of the muscles of both hands. Kyphosis was present in the lumbar region and the deep reflexes were absent.

Bruns, in considering these cases, says they are undoubted cases of Werdnig-Hoffmann's disease. He notes the difference in age between his cases and those of Werdnig and Hoffmann, but he says that they cannot be mistaken for any progessive form of muscular dystrophy. He suggests that Charcot-Marie-Tooth or peroneal is the type which most resembles these cases, but the atrophy in these begins in the peripheral portion of the limbs and extends upwards.

I should not be prepared to agree with this statement, for the cases rather closely resemble some of the forms of dystrophy, which begin in the proximal muscle, and a very similar case with curvature of the spine has been figured by Jendrassik (see Case 10, *Deutsche Zeitschr. f. Nervenheilk.*, 1902, Bd. xxii, S. 444). Without a pathological examination Bruns is hardly justified in placing in the Werdnig-Hoffmann group a type of case which differs so markedly in course and clinical features from that group.

Senator describes two cases, a brother and sister, under the title "Zur Kenntniss der familiarem progressive Muskelatrophie in Kindesalter."

The first case is that of a boy, aged 8, healthy at birth. He walked at 11 months. When 2 years old he often fell. Walking and standing became more difficult, so that when 3 years he had nearly always to be carried. He learnt to write, but when between 6 and 7 he lost this power, owing to the shaking of his hands. His memory also began to fail. There was atrophy of the shoulder and upper arm muscles, atrophy of the back muscles, moderate lordosis and the muscles showed fibrillary tremors. The knee-jerks were absent, sensation was natural. There was altered electrical excitability. Six months later the atrophy of the buttocks and shoulders had made further progress. The gait was unaltered. He was neither better nor worse.

The second case, G. S., a girl, aged 5½, walked at 10 months. When 18 months old she had a fit. When 2 years old she became unsteady on her legs, like her brother, and at the same time there was tremor of the hands. She walked with a wide base, was shaky, had marked lordosis and a lateral curvature with the convexity to the right. There was wasting of the back muscles and to a lesser degree of the upper arm and pectoral muscles. The buttock muscles were flabby, but the lower legs appeared well developed. Fibrillary tremor was present in some muscles. There was diminished excitability in the muscles.

Senator, in considering the differential diagnosis of these cases, questions whether they belong to the neuropathic form of Werdnig and Hoffmann, or to Erbs' myopathic form of simple atrophy. He says that Heubner, Schulz and Preisz have shown changes in the nervous system in some cases of myopathy. He thinks these two cases are probably spinal in origin.

Lange describes two cases, a brother and sister, aged 11 and 6 respectively, the first and fourth children of a family of six. The second child was said to have died of a similar complaint when 3 years old.

The first case, a boy, did well for the first nine months of life, then he began to lose power in the limbs, lost the power of sitting up, and also the power in the neck muscles. When 3 he developed double cataract.

When 11 years old he was unable to stand, there was marked wasting of the proximal muscles of the limbs. The shoulders were loose. The knee-jerks were absent.

The second child, sister of the above, aged 6, was quite well till 9 months. Then the legs began to waste. She never learnt to walk. When 3 years old she, like her brother, developed cataract. She could only sit when propped up.

Lange is inclined to attribute these cases to the Werdnig-Hoffmann group, but he says it is impossible to separate such cases from the myopathies without a pathological examination.

In conclusion, as belonging to the Werdnig-Hoffmann group one would accept in addition to the case of Hoffmann, published in 1900, Beevor's case, von Ritter's two cases, Armand-Delille and Boudet's case, all with the pathological examination, and also Sevestre's and Wimmer's first case without a pathological examination. I should not, however, be prepared to accept as belonging to this group the cases of Bruns, Senator and Lange without a pathological examination.

The following list of thirteen cases comprises all those in which the diagnosis has been confirmed by autopsy, and may be accepted as belonging to the Werdnig-Hoffmann type. They have been arranged according to the age at which death occurred. The list shows the marked variation in the duration of symptoms.

Recorder	Age of onset	Sex	Age of child	Family history	Year of publication
1. Batten ..	14 days ..	M.	5 weeks ..	0	1911
2. Beevor ..	Birth	M.	2 months ..	Yes	1900
3. Armand-Delille and Boudet	2 months ..	M.	6 months ..	0	1908
4. Batten ..	Always weak ..	M.	8 months ..	0	1911
5. v. Ritter ..	5 months ..	F.	15 months ..	0	1904
6. v. Ritter ..	12 months ..	F.	2 years	0	1904
7. Hoffmann ..	7 months ..	F.	2½ years ..	Yes	1897
8. Werdnig ..	10 months ..	M.	8 years	Yes	1891
9. Batten ..	Always weak ..	M.	3½ years ..	0	1911
10. Hoffman ..	9 months ..	F.	5 years	Yes	1893
11. Hoffman ..	4 months ..	F.	5 years	Yes	1900
12. Werdnig ..	10 months ..	M.	6 years	Yes	1894
13. Bruce and Thomson	12 months ..	F.	6 years	0	1893

SUMMARY.

The paper deals with the widespread progressive muscular atrophy of infants and young children due to a spinal lesion. The paper is based on the clinical and pathological examination of eight cases. These, on pathological grounds, are divided into three classes:—

(1) A type of case in which progressive muscular weakness occurs during the first week or month of life, gradually progresses, and terminates in death after a variable period of weeks, months, or years. Sometimes more than one member of the family may be affected. The pathological change found in these cases is a degeneration of the lower motor neurons, the character of the change depending on the time after the onset of the disease at which death takes place. The type corresponds to the cases described by Werdnig and Hoffmann.

(2) A type of case in which progressive muscular weakness and atrophy begins somewhat later in life, after the child has already walked, and slowly progresses till death occurs from respiratory failure or pneumonia. The pathological changes found in such a case resemble those found in a toxic neuritis.

(3) A type of case in which progressive muscular weakness and atrophy begin in later life, after the child has already walked, slowly progresses, and is attended by a widespread myelitis of the spinal cord.

Six of the recorded cases are assigned to the first group, one to the second, and one to the third.

The literature is then considered. Ten cases belonging to the first group are at present on record with a pathological examination; two recorded by Werdnig, three by Hoffman, two by v. Ritter, one by Bruce and Thomson, one by Beevor, and one by Armand-Delille and Boudet.

Of recorded cases assigned to the Werdnig-Hoffmann group without an autopsy, the writer is unwilling to accept those of Senator, Bruns, Lange, and the second case of Wimmer's, but would accept Wimmer's first case, and that recorded by Sevestre.

The great difficulty in the diagnosis of these cases from cases of primary myopathy is recognized, and reference is made to cases recorded by Finkelnburg, which on clinical grounds might well be assigned to primary spinal atrophy, but on pathological grounds was shown to belong to the myopathic group.

APPENDIX.

Case 1.—Charles H., aged 4 weeks, was seen at the Children's Hospital, Great Ormond Street, in May, 1903. The child was the first. The parents were healthy. There had been no miscarriages, the labour had been prolonged, but no instruments had been used. At birth the cord was round the child's neck, and the child was cyanosed. The child was breast-fed for the first fourteen days and seemed to thrive. It was then fed on goats' milk. Wasting and loss of power in the limbs was first noticed when the child was 14 days old, and the child gradually became feebler. The child sucked well, but seemed to get easily tired. There was no vomiting. The child had been rather constipated. On examination the child was small, wasted, weighing 5½ lb. It lay with the arms at its side and did not attempt any movement. Respiration was feeble, the pulse from 84 to 96 per minute. The child seemed to see and to take notice. The eye movements were good, it sucked well, and there was no paralysis of the tongue or palate. There was no regurgitation; it cried fairly well; there was complete flaccid paralysis of the muscles of the neck.

The arms lay quite flaccid by the side or across the abdomen, or wherever placed. The child was just able to move the fingers, the arms were thin and wasted. There was no power in the muscles of the back, and very little in the intercostal or abdominal muscles. There was almost complete flaccid palsy of all the muscles of the leg, but some slight movement remained in the toes. The knee-jerks were absent. The child certainly felt a pin-prick all over the body.

On electrical examination of the muscles no contraction could be obtained to strong faradic current in any of the muscles of the arm, trunk, or leg. The child died three days after admission to the hospital. On *post-mortem* examination nothing abnormal could be found on naked-eye examination in the visceral or nervous system. The brain and spinal cord, the right median, the right phrenic, left sciatic nerves, and biceps muscle were preserved for examination.

The examination of the tissues was carried out by the Marchi, Nissl, Weigert-Pal, and Van Gieson methods.

Microscopical examination.—The spinal cord by the Marchi method showed at the level of a third sacral segment marked degeneration in the finer fibres of the grey matter of the anterior horns (fig. 4). These degenerate fibres arising from the cells of the anterior horn form bundles which can be seen passing through the white matter of the cord towards the peripheral, where they form, after their exit from the cord, the anterior roots. Numerous degenerate fibres can be seen in these anterior roots (figs. 2 and 3). The fibres of both anterior horns are about equally affected. The cells of the anterior horn appear for the most part normal and show no evidence of pigmentation or degeneration. It is not possible to assert that one group of cells have more degenerate fibres arising from them than another group. No degenerate fibres could be seen in the antero-lateral tracts other than those above mentioned, which were passing outwards to the anterior roots. In the posterior columns, however, a few degenerate fibres could be seen in the posterior root zone, and also in the posterior roots both within the cord and outside.

At the level of the third lumbar a similar condition was present—viz., degeneration of the fine fibres passing from the anterior horns to the anterior roots. A few degenerate fibres were also present in the posterior columns and roots.

At the level of the first lumbar the degeneration becomes less marked, but a few degenerate fibres can now be seen in the region of Clarke's column, and although they cannot be traced to the direct cerebellar tract, yet they tend in that direction, and scattered degenerate fibres can be seen in this tract. A few degenerate fibres are present also in the posterior columns and roots.

Throughout the dorsal region but little degeneration can be seen (fig. 1). There are a few degenerate fibres in the anterior horns and also in the posterior columns, but the cells of Clarke's column appear normal, and there are no degenerate fibres in that region. (Figs. 1, 2, 3, 4.)

At the level of the first and second dorsal segments degenerate fibres again become more numerous, and at the level of the sixth cervical segment marked degeneration is again present in the grey matter of the anterior horns (fig. 1.) The degeneration is more marked about the median group of cells, and least about the lateral group. In the posterior columns there are a few degenerate fibres, whilst there are practically no degenerate fibres in the antero-lateral tract. All through the cervical region there is considerable degeneration which, however, becomes less marked again in the upper cervical segments. There is a small bundle of fibres situated at the root of the posterior horn, which contains degenerate fibres; this can be traced from the seventh cervical segment upwards to the lower portion of the medulla, where it apparently leaves the cord by a lateral nerve-root (spinal accessory fibres).

By the Nissl method the cells of the anterior horn appear numerous, and for the most part well stained. Here and there individual cells may show some chromatolysis, but the greater part of the cells are normal, both as to number and character. (Figs. 5 and 6.)

By the Weigert-Pal method the cord appears normal for a child of this age, although the pyramidal tracts are not fully medullated.

By the Van Gieson method there is no evidence of vascular or interstitial change.

Brain.—No change could be found in the cortex of the cerebral hemispheres, in the cerebellum, or in the pons. In the medulla a few degenerate fibres can be seen in the intramedullary course of the twelfth nerve.

The peripheral nerves, the right phrenic, the left sciatic, the right median, examined by the Marchi method, do not show any degeneration, and also appear normal by other methods of examination.

The biceps muscle does not show any marked change. The muscle-fibres are in the infantile condition, uniform in size, there is no fibrosis, and the intramuscular nerves are relatively well stained.

The result of the examination of this case is to show that degeneration has taken place in the lower motor neurons. The changes present are similar to those seen in diphtheritic paralysis—viz., a marked degeneration of the myelin sheath, as shown by the Marchi method, and comparatively little change in the cells of the anterior horn.

Case 2.—William G., aged 5 weeks, was admitted to the National Hospital under the care of Dr. Beevor. The child was the eighth of eight children, four of whom had been similarly affected, viz., the first died at 4½ months, the second died at 8 months, the fourth died at 7 months, and the eighth (the patient) died at 2 months.

The child was full term, there was difficulty with the labour, and he was noticed to be paralysed at birth.

On examination there was complete flaccid paralysis of all four limbs, with the exception of very slight involuntary movements of the fingers of the left hand. Sensation was said to be lost on the limbs and on the trunk to the second rib. All the deep reflexes were absent.

The pathological examination showed no macroscopic change, but on microscopic examination atrophy of the cells of the anterior horns (figs. 7 and 8) and degeneration of the posterior columns were found.

For a full clinical and pathological report of this case see BRAIN, 1902, xxv, p. 85.

Case 3.—Edward T., aged 4 months, was admitted to the Children's Hospital, Great Ormond Street, under the care of Dr. Penrose, in October, 1901.

History.—General helplessness was first noticed one week after birth, and had steadily increased since. The limbs wasted and the breathing became difficult. There was some difficulty in swallowing at times. The child is the fourth of four children. The first is alive, aged 4, and is well. The third child died at 5 months and is said to have had a similar condition to the present patient.

Present condition.—The child lies on its back, crying feebly, but employing all its facial muscles. There is no facial asymmetry. The thorax is quite motionless in breathing; while the abdomen moves freely. There is marked wasting of the shoulder muscles and those of the limbs. The child can apparently do nothing except make a slight movement of the toes. The forearm can be feebly flexed and extended and all movements of the upper arm are capable of being feebly performed, though the child does not raise the arms above the shoulders. The wrists are dropped. The child is absolutely unable to sit up, and when raised the head falls about helplessly. Fibrillary tremor is noticed in the muscles of the arm. The movements of the tongue and eyes appear normal. The deep reflexes are absent and the plantar response, when it can be elicited, is in the direction of the extension of the small toes. The child died. No *post-mortem* was obtainable.

Case 4.—Percy B., aged 6 months, fourth of four children. One died of fits at 4 months, due to injury at birth. One died of tuberculosis. The boy was born at full term, and the labour was natural. He was said by the mother to be healthy at birth. When 4 months old it was noticed that the child could not move the arms. The onset seems to have been quite gradual.

On admission to hospital the child was well nourished, lay on its back taking notice of all around it, smiling, and seemed quite intelligent.

Both arms lay by the side absolutely flaccid, except for some movements of the fingers. Both legs were quite flaccid and powerless. Respiration was almost entirely abdominal, and there seemed to be paralysis of the intercostals. The neck muscles were quite powerless. All the deep reflexes were absent; superficial reflexes indefinite. Sensation apparently perfect. On electrical examination practically no contraction could be obtained to faradic stimulation, except in the flexors of the fingers, and then only with a current which will produce a tetanus in the muscles of a normal individual. To galvanism no definite contraction obtained.

The fundus of the eyes was examined and appeared normal. The child developed broncho-pneumonia and died. No autopsy was obtainable.

The clinical features which this child presented seem to be almost typical of the progressive muscular atrophy of infants, but without the verification of a *post-mortem* the case loses much of its importance.

Case 5.—H. Clarke, aged 8 months, was the third of three children, the other two being healthy. The child had been breast-fed; he had had no difficulty in swallowing and had had no illness. The birth of the child was natural. The history was that the child had always been weak and had never been able to sit up, nor could he hold up the head. The weakness seems to have increased, and when first seen, besides the weakness of the neck muscles above described, the arms were perfectly flaccid, the deltoids being especially weak. The legs were flaccid, only the slightest movement being possible. The knee-jerks were present, but only obtained with difficulty, and the plantar usually gave a flexor response.

There was marked weakness of the back, with a lateral curvature, the concavity being to the left. The pupils were equal.

The child developed broncho-pneumonia and died in a few days.

At the autopsy there was extensive broncho-pneumonia. There was a marked lateral curvature of the spine to the left. The spinal cord and membranes appeared normal. There was no wasting of the cord. Brain appeared normal. All the muscles very pale, but not atrophied. Diaphragm looked a good colour.

Pathological examination.—The cord was examined by the Marchi, Nissl, and Van Gieson methods. The cells of the spinal cord appear to be fairly numerous, and show only slight chromatolysis. In most of the cells the nucleus is centrally placed. The anterior nerve-roots do not appear unduly small.

Examination by Marchi method shows a certain amount of degeneration in the anterior roots very similar to that found in the Case 1, but to a far less degree.

There was in this case no microscopical examination of the peripheral nerves or muscles.

Case 6.—R. A., a boy, aged 3½, was admitted into the Hospital for Sick Children, Great Ormond Street, under the care of Dr. Garrod, June, 1910. He was one of twins; the other (a male) is healthy. This child cut his first tooth at 8 months, and learnt to talk early. The boy never learnt to sit up, and when 15 months old it was noticed that he could not move his legs. He, however, moved his arms quite well. When 2½ years old he was seen by a surgeon, who ordered him a Phelps' box in which he was kept lying down.

The boy is the result of the fifth pregnancy. The eldest child, aged 15, is alive. There has been one miscarriage and two children stillborn.

The boy lies on his back and he can be freely moved about without pain. He is intelligent and can talk well. There is no affection of the ocular nerves. He is quite unable to sit up, nor can he maintain the sitting posture when sat up. He can, however, hold up his head. He can move the arms about fairly well, but there is some contraction of the outer phalangeal joints which limits his movements. There is a peculiar "athetoid" movement of both hands, and when he grasps an object he overdoes the action. The legs lie flaccid in bed, but the right knee-joint cannot be extended more than 35°. The legs are generally wasted and flabby and there is wasting of both lower limbs, especially above the knee, and this is rather more marked on the right side than the left. The right thigh is adducted and the adductor muscle is contracted. There is genu valgum and talipes valgus on the right side. There is no power of movement in the lower limbs, but they can be freely moved passively, and there is marked flaccidity, except for the contraction above mentioned.

There was well-marked lateral curvature in the lower dorsal region, with convexity to the right. The muscles of the back were wasted. There was no tenderness.

The left knee-jerk was present, the right was absent. No plantar response was obtained. The abdominal reflex was present on the left, absent on the right side. Sensation was perfect. Electrical examination showed greatly diminished excitability to both faradic and galvanic current.

I saw the boy in June, 1910, and from the clinical features came to the conclusion that the case was probably one of old and extensive poliomyelitis. I failed to recognize the progressive nature of the case and attributed his continued weakness to the fact that he had been kept for a year in a Phelps' box. On July 8 he had some retention of urine, which was relieved by the catheter. This retention passed off on the 12th. X-rays showed no disease of spine.

On August 24 intercostals became very weak. Broncho-pneumonia developed, and the child died on September 3.

The *post-mortem* showed some patchy broncho-pneumonia. The brain and spinal cord appeared normal to the naked eye, except that the anterior roots appeared smaller than normal. The posterior roots were well developed. The spinal cord was examined by the Marchi, Weigert-Pal, Nissl, and Van Gieson methods.

By the Marchi method practically no recent degeneration could be found. There were in the grey matter of the anterior horns in the cervical region a few fibres which showed degeneration, but they were very few in number.

By the Weigert-Pal method the whole of the white matter of the antero-lateral tracts was paler than the posterior columns, but no tract could be said to be definitely affected. There was no diminution in the size of the grey matter, and the medullated fibres in the grey matter appeared fairly normal. The most striking feature was the smallness of the anterior roots as compared with the posterior, and the great diminution of fibres. The most marked change was to be seen in sections stained by the Nissl and Van Gieson methods. The absence of cells in the anterior horns, both in the lumbar, thoracic and cervical region, is most striking. In any given section one or two normal cells can generally be seen, but the other cells are small, apparently well formed, but only about half the size of the normal cell. Many cells must have entirely disappeared. If the number of cells of moderate size are counted in a series of sections in the lumbar region, they average out about ten to a section, whereas the normal average out to about forty, and these figures do not truly represent the state of affairs, for the size of the cells in this cord is somewhat smaller than in the normal cord. (Figs. 9 and 10.)

Case 7.—Hetty M., aged 3, the youngest of four healthy children, was admitted to the Children's Hospital, Great Ormond Street, under the care of Dr. Voelcker, in October, 1908. She was healthy at birth, and well up till ten weeks ago, when it was noticed one morning that she was unable to walk properly and fell backwards into a sitting position after taking a few steps. On stooping she was unable to regain the upright position. She had incontinence of urine and fæces. The arms were said to be unaffected and the child was able to feed herself. There had been no constitutional symptoms.

Seven weeks later the arms became weak, causing her difficulty in feeding herself. There was irritability, but no evidence of pain.

She is a bright, intelligent, and well-nourished child. She can move her legs, but cannot stand. There is weakness of both deltoids, but the forearm muscles are good. The cranial nerves, optic discs, and trunk muscles are normal. Sensation is unimpaired. All the deep reflexes are absent, but the abdominals are present and the plantars give an indefinite response.

When at first in the hospital there was a definite increase of muscular weakness. The arms became powerless, only movements of the fingers and slight movements of the wrists remained. The back muscles were weak, and there was a curvature, with the convexity to the right. The legs became weaker and more wasted. A definite weakness of the right side of the face developed. This passed off in a few days. There was the reaction of degeneration in the muscles of the lower limbs.

In December, some two months after admission to the hospital, there was a gradual improvement, so that the child could now get the hand up to the mouth and move its legs. The knee-jerks were still absent. This improvement was maintained till February, 1909. The weakness then again began to increase, the intercostal muscles and diaphragm became affected, and in October, 1909, the child died, twelve months after admission to the hospital, and fourteen months after the onset of the disease.

On *post-mortem* examination nothing abnormal to the naked eye could be found in the brain or spinal cord.

The cord and medulla were examined by the Weigert-Pal, Nissl, Marchi, and Van Gieson methods.

The cord examined by Weigert-Pal method appeared perfectly normal.

By the Marchi method: There was scattered degeneration throughout the length of the spinal cord. The amount of the degeneration was slight, and could not be said to affect any particular tract of the cord. If anything, the anterior and posterior roots in their passage through the white matter of the cord were rather more affected than other parts. There was a little fine degeneration in the grey matter in the region of the anterior horns. The intramedullary portions of the twelfth nerve also show some fine degeneration. The extramedullary portion of the anterior and posterior roots practically show no change.

By the Nissl method: The cells of the grey matter are well stained. Many of the cells of the anterior horns in the lumbar, thoracic, and cervical regions of the cord appear perfectly normal. Some cells, however, in each region of the cord show chromatolytic changes. These changes are not confined to any one group of cells, but affect individual cells in any group, a cell in close proximity being perfectly normal. (Figs. 11 and 12.)

The changes which these cells exhibit are a somewhat swollen appearance, the nucleus being eccentric, but the nucleolus well stained.

The chromophylic substance of the cells stains diffusely, and it is only at the margin of the cell that the normal chromophylic granules can be seen.

There are very few cells that can be said to be in a state of profound degeneration, and in most of those affected the change is comparatively slight.

The cells of Clarke's column also show some changes.

By the Van Gieson method: The interstitial tissue and the vessels of the cord appear perfectly normal, and there is no evidence of either past or present inflammation.

The peripheral nerves examined were those of the sciatic and brachial plexus.

By the Marchi method: A very considerable amount of degeneration of the myelin sheath could be seen. This was more marked in the nerves of the brachial plexus than in the sciatic.

By the Van Gieson method: The same nerves appear perfectly normal, and there is no evidence of interstitial inflammation.

The muscle-fibres of the diaphragm show most marked fatty degeneration when stained by the Marchi method.

The changes found in this case point to a toxic degeneration of the lower motor and sensory neurons. Since the changes are more marked in the peripheral nerves than in the cell body, the case would fall into the group known as toxic neuritis. The clinical course and symptoms do not, however, correspond with those commonly associated with that disease.

Case 8.—Matilda L., aged 11. Twelve months, weakness of hands. Seven months, unable to button clothes. Four months, weakness of legs. Two months, adenoids removed, and much worse since that operation. Fourteen days, pain in back, and increasing difficulty in swallowing.

Intelligent, deaf, some atrophy of tongue, palate moves well on phonation, weakness of neck, respiration thoracic, upper intercostals only in use. Claw hand, wrist-drop. Weakness of upper arm and shoulder muscles. Can walk, but only feebly. Knee-jerks brisk, plantar flexor, sensation natural to all forms.

Electrical reaction R.D. in some muscles, in others only diminution of irritability. Sudden death from respiratory failure six months later, eighteen months after onset of disease.

Pathological examination showed an extensive destruction and atrophy of the cells of the anterior horn, from the upper cervical to the lower thoracic segment, extensive degeneration of the whole of the ventral region of the cord in the thoracic segments. Degeneration of the direct cerebellar tracts both dorsal and ventral.

There was a marked increase of the connective tissue in the ventral portion of the cord in the thoracic region.

The walls of the vessels showed no change. The cord showed both recent and old degeneration.

The change in the cord is attributed to a chronic myelitis secondary to some vascular change and toxic blood state. For full clinical and pathological report of the case, see BRAIN, 1903, xxvi, p. 473.

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THE INDEPENDENCE OF THE PERIPHERAL SENSORY NEURONE IN VIEW OF THE RESULTS OF EXPERIMENTAL SECTION OF THE OPTIC NERVE IN TH RABBIT.[1]

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PART I.—INTRODUCTION.

PART II.—PRESENT INVESTIGATION.
- A. Results of Experimental Section of the Optic Nerve.
  - (i) Operative Technique.
  - (ii) Histological Methods.
  - (iii) Experimental Details.
  - (iv) Discussion of Results.
- B. Results of Autolytic Experiments.
  - (i) General Remarks.
  - (ii) Experimental Details.
  - (iii) Discussion of Results.

PART III.—CONCLUSIONS.

PART I.—INTRODUCTION.

ALTHOUGH in the general sense one may accept the neurone theory, viz., that the nervous system consists of innumerable anatomically independent cellular units, the processes of which exist in contiguity, but not continuity, with each other [39], the mutual relationship and interdependence of the neurones is a problem as yet unsolved. This is specially the case as regards the peripherally placed neurones. The object of the present investigation was to throw light upon the question. The retinal neurones were selected for the purpose of experiment, the plan being to separate them from their central connexion by section of the optic nerves, without interference with the vascular supply of the retina.

In the retina the cells of the peripheral neurones are those of the outer and inner nuclear layers, and, although the small size of these neurones renders them more difficult of observation than could be

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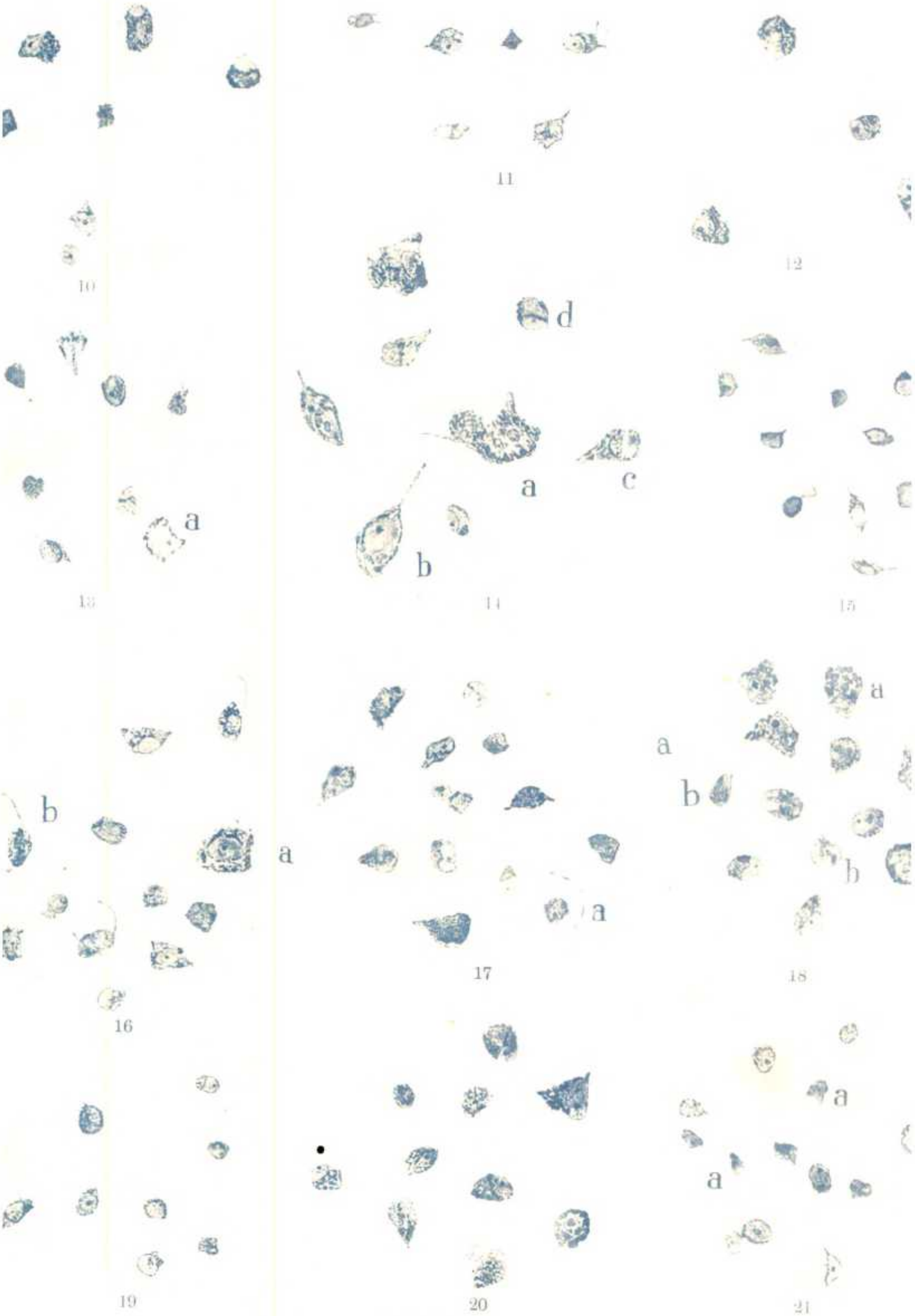
[1] The expenses of this research were defrayed by a grant from the Carnegie Trustees.

PLATE I.



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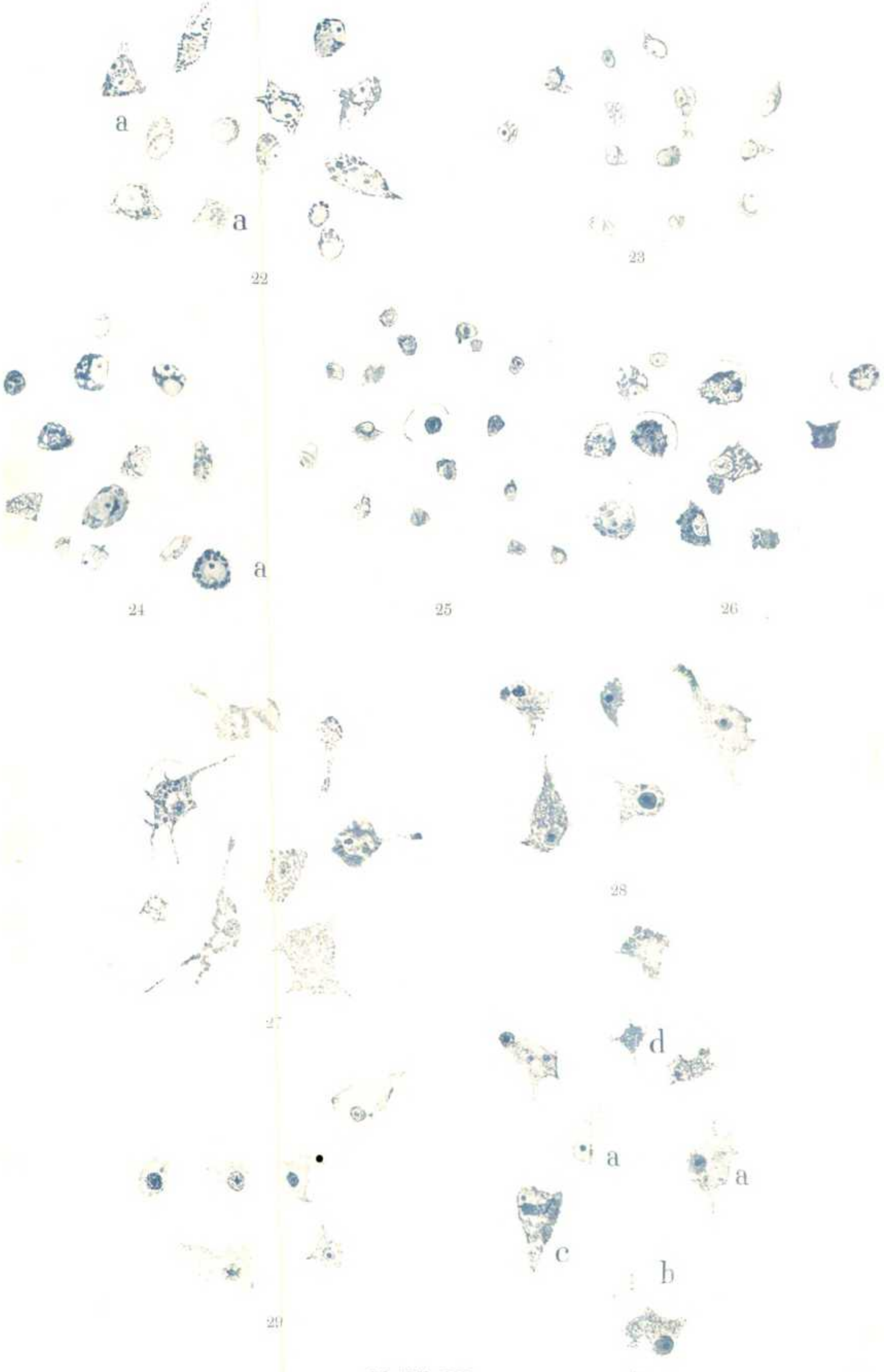

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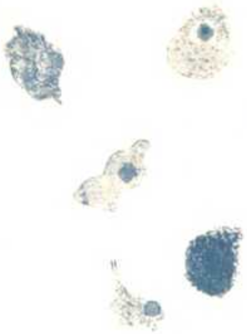

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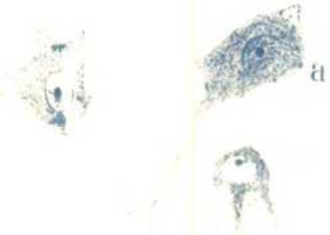

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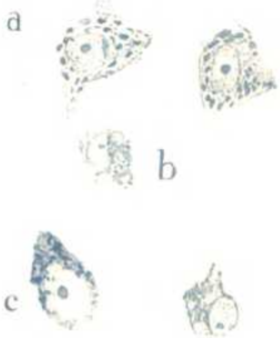

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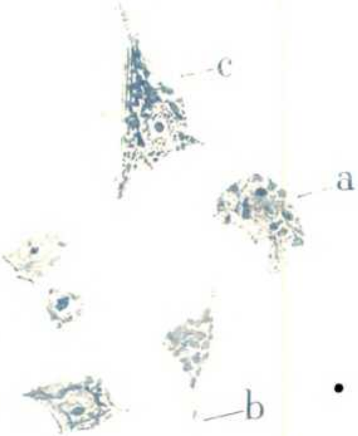

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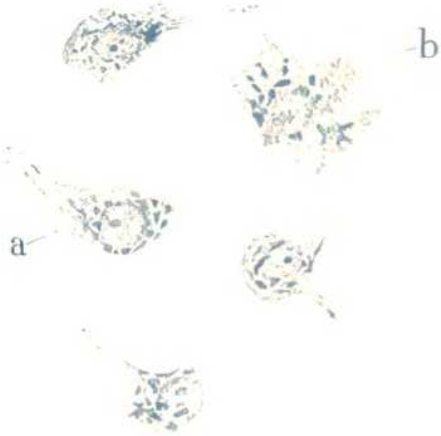

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PLATE IV.

desired, yet the comparative simplicity of their structure makes the histological examination tolerably easy.

The cells of the ganglionic layer, on the other hand, are conspicuous by their size and structural definition, and their condition was studied in each experiment.

Ontogeny of the Visual Peripheral Sensory Neurone.

The retina develops as a hollow outgrowth from the primitive fore-brain, the stalk which connects these two structures persisting as the optic nerve. The ganglion cells are the cells of the innermost cellular layer, and are in connexion with the optic nerve-fibres which conduct stimuli through the various stations of arborization (corpora quadrigemina, corpora geniculata externa, and optic thalamus) to reach the visual cortex. The retina, optic nerve and optic tract are thus developmentally part of the central nervous system.

With regard to the relations of the retinal elements, two views are held. According to the one which is advocated by Barker [4] the bipolar cells of the inner nuclear layer are analogous to the spinal peripheral neurones of the dorsal roots, the ganglion cells of the retina corresponding to neurones of the second order (*i.e.*, the neurones of the grey matter of the spinal cord). One must not drive such a comparison too far, and the alternative view, that the ganglion cells of the retina are analogous to the dorsal spinal ganglia, is more generally accepted. The bipolar cells of the inner nuclear layer are the peripheral sensory neurones which have their peripheral processes in contact with the central process of the still more peripherally situated cells of the external nuclear layer. It is the aim of the present investigation to follow the fate of the neurones situated distal to the site of injury in the optic nerve.

Owing to limitations of space it is impossible to give a critical review of the general literature bearing upon the present research; a bibliography of the more essential of the published works will be found at the end of this paper. With regard to the experiments performed by other workers, section of the optic nerve has formed the subject of numerous publications. The results of these experiments are of little or no assistance to us, since the purposes for which the investigations were instituted were other than the present, and the histological methods—of the earlier workers at least—were inappropriate. An exception, however, is to be made in the case of Birch-Hirschfeld

[8]; who published in 1900 the first of a series of retinal experiments, including section of the optic nerve.

The value of his work is enchanced by the fact that he employed the Nissl method, and described the fine histological appearances in minute detail, so that his results have been taken as a guide in the present investigation. He covered a wide field in his experiments, investigating the behaviour of the retina in the rabbit under the influence of different pathological conditions, viz., electrical and thermal stimulation, section of the optic nerve, and poisoning with various drugs (methyl-alcohol, nicotin, quinine, &c.).

The results he obtained from section of the optic nerve must now be summarized more or less in detail.

His operations were performed as far back as possible in the orbit, in order to avoid injury to the vessels. In some cases he operated from above, by means of a knob-pointed knife, and, although the operation was practically bloodless, the ophthalmoscope showed almost immediate contraction of the retinal arteries. In one case he cut the nerve intracranially, close to the optic foramen.

In his anatomical investigation he found considerable divergence from the normal fifty-five hours after operation, when chromatolysis had already begun in the case of the ganglion cells. The chromatin clumps had lost their sharpness of outline. The nucleus was large, swollen, diffusely stained, and often almost touched the cell wall. The cells of the internal nuclear layer were small, full of chromatin, and often irregular in outline. The cells of the outer nuclear layer were roundish, devoid of edge-crenation, and showed only partial cross-striping. Cases examined at five, ten, and fifteen days after operation revealed still further advanced chromatolysis, shrinking of the ganglion cell (shown by the increased pericellular space) and its nucleus. The normal Nissl granules had been replaced by a darkly staining, badly defined, crumbling mass, or were altogether wanting, their place being taken by vacuoles of different sizes. He emphasized the fact that these vacuoles were absent from the control.

Valuable as are these results, it was felt that as his attention had been chiefly directed to the ganglion cells, and as the object of the present investigation was to study the peripheral neurones, a further series of experiments was desirable.

PART II.—PRESENT INVESTIGATION.

A. Results of Experimental Section of the Optic Nerve.

(*i*) *Operative Technique.*

The operation was performed with the usual aseptic precautions and under full anæsthesia. The animal having been placed in a good light on the operating bench, the eye to be operated upon (in all cases, except one, the right) was douched with tepid sterile water. The conjunctiva was picked up in dissecting forceps, and was incised in a line parallel to the corneal margin, and situated about 4 mm. from it. This incision extended for about 1 cm. on either side of a point opposite the middle of the supra-orbital margin.

The wound was then deepened by gentle separation of the conjunctiva from the underlying structures, as far back as possible. The superior rectus muscle was sometimes divided, but in many cases this was not necessary. The "corneal" flap of the wound was then grasped in fixation forceps, and the eyeball rotated downwards. By gentle manipulation the eye was raised out of the orbital cavity (it was sometimes necessary to divide the outer canthus at this stage, if the palpebral fissure was small), turned sharply downwards and retained in this position by the assistant. In this way the optic nerve (which in the rabbit enters the sclera above the horizontal meridian) came to lie high up in the wound, and the nerve after a little careful dissection could be isolated. The dense tissue of Tenon's capsule which forms a funnel-shaped investment for the nerve is liable to cause trouble at this stage, and the delicate vessels are easily damaged in making way through it. The nerve appeared as a slender glistening white cord and, having been lifted up on the tenotomy hook, was divided far back (*i.e.*, clear of the central vessels) by means of scissors inserted, closed, and then opened merely enough to include the nerve. When traction was removed, the eyeball readily slipped back into the orbital cavity. Hæmorrhage, when it occurred, as a rule, took place at the stage of deepening the original incision, *i.e.*, in the region of the anterior vessels of the globe. It was usually easily controlled by pressure. The hæmorrhage which was met with when the nerve was divided was no doubt due to the inclusion of some of the branches of the central artery, but was of infrequent occurrence, and was soon controlled. In a few cases ulceration of the cornea ensued, due either to slight abrasion at the time of operation or to an atrophic condition, the result of lesion of some of the long anterior ciliary nerves. The ulceration subsided in a few days (under boracic douching), leaving a small leucoma.

In all cases total and permanent blindness of the eye appeared to follow from the operation, although the difficulty of estimating the amount of visual perception in a rabbit makes one reserved in any statement regarding the physiological condition.[1]

The pupil, which usually contracted to a pin-point at the moment of division of the nerve, gradually dilated, and remained semi- or fully-dilated and inactive to light. Ophthalmoscopic examination of the fundus never revealed more than some slight narrowing of the retinal vessels, with pallor of the " medullary rays " in the late stages.

The experiments recorded are those in which section of the optic nerve was uncomplicated by injury to the retinal vessels, or by lasting inflammation.

(*ii*) *Histological Methods.*

In every case the same treatment was adopted for the control as for the experimental material.

Fixation.—For successful demonstration of the Nissl granules, the most satisfactory fixative was alcohol (50 per cent. to 75 per cent.). The tissue remained in this from a half to several hours, according to the size. Dehydration in several changes of absolute alcohol. Clearing was least injurious when carried out in cedar-wood oil. Other fixatives employed, with less satisfactory results, were: $HgCl_2$ (saturated saline solution), formol-saline (10 per cent. formalin in normal saline solution), and picro-formol (saturated watery solution of picric acid 75 parts, formol 25 parts, acetic acid 5 parts).

Staining.—Nissl granules in every case were stained by toluidin blue, no counter-stain being employed. (Methylene blue and thionin did not yield good results.)

Other stains for general demonstration were hæmalum and eosin; and Weigert's rapid iron-hæmatoxylin method.

Silver impregnation.—The chrome-silver method of Golgi was unsuccessful in these experiments, although a fair amount of success was obtained in the case of the ox-retina.

The method of Cajal (formula II) produced very beautiful results in many cases, but was seldom satisfactory in control and experimental material of the same case.

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[1] The method adopted was that of flashing the brightly illuminated ophthalmoscopic mirror on to the eye in the dark room. The response which, in the case of the control, was immediate, although not very vigorous, and consisted in twitching of the eyelids and shunning of the light, was found to be entirely absent in the operated eye.

Cox's method of sublimate and bichromate impregnation was not found satisfactory.

Ehrlich's intra-vitam method (Dogiel's modification) of methylene blue impregnation was employed successfully in one or two cases, but was not of much practical value in these experiments.

(*iii*) *Experimental Details.*

Experiment I.—Adult albino. Thirty-four hours after operation no microscopic changes were discovered in the operated eye.

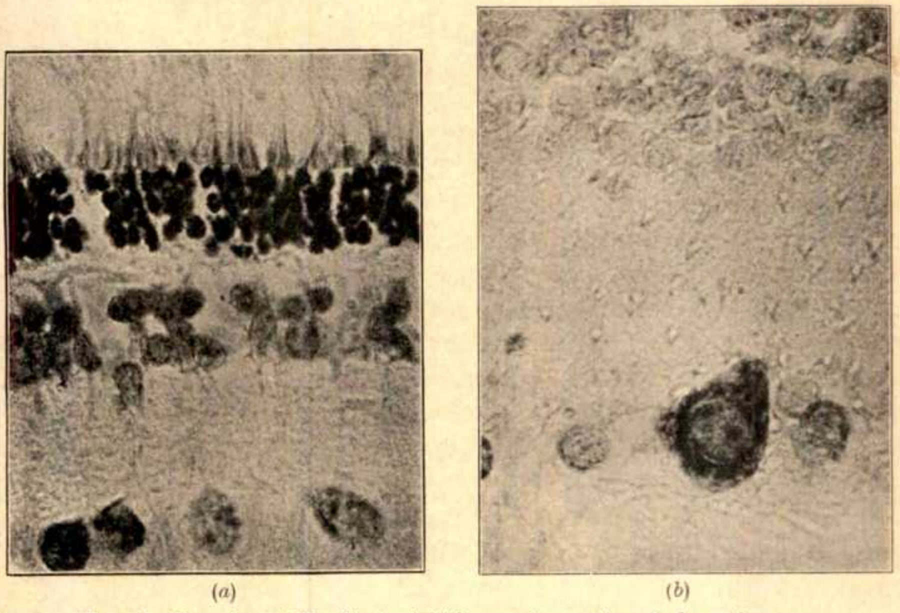

(*a*) (*b*)

FIG. 1.—Experiment II. Forty-eight hours after section of the optic nerve.

Operated. Tol. B. Photomic. × 1,000. Showing ganglion cells somewhat diffusely stained. In the one to the left the nucleus is eccentric. The outer retinal layers are normal.
Control. Tol. B. Photomic. × 1,000. Showing large ganglion cell with discrete chromatin granules and centrally placed nucleus. The outer layers are not seen.

Experiment II.—Adult albino. Forty-eight hours (fig. 1). Operation practically bloodless. No inflammation ensued. Fixation of retina in 50 per cent. alcohol and in 10 per cent. formalin. Sections stained by toluidin blue and by Weigert's iron-hæmatoxylin method. Impregnation by Cajal's silver method was unsuccessful.

Microscopic examination.—The outer layers of the retina showed no abnormality in the operated eye. The nuclei of the rods showed the chromatin arranged in the usual form of twin masses separated by a considerable interspace—an arrangement which may be described by the term "cross-striping." The fine serration of the edges of these masses, due to the presence of fine strands of chromatin passing out to the cell membrane across the intervening space, for convenience of description may be designated as "cog-wheel" markings. In the operated eye these features were as distinct as in the control. The larger and more complex nuclei, generally looked upon as belonging to the cones, showed no variation from the normal, having the typical arrangement of the chromatin (*i.e.*, three or four masses with cruciform interspace). They were much less numerous than the rod-nuclei. The cells of the internal nuclear layer were normal and showed the chromatin arranged in the form of a loose, tangled, granular skein or network.

With regard to the cells of the ganglionic layer, a certain amount of blurring of the outline of the Nissl bodies was met with in the operated eye. Considerable variation in staining power was to be seen in the control, instances of cells in which the protoplasm was deeply and diffusely stained being fairly common. Most of the cells, however, in the control showed a high degree of differentiation of chromatin which was practically never met with in the operated eye.

The fact that one found in the normal many cells exhibiting the phenomena which, in the case of the cells of the central nervous system are usually classified as pathological (viz., eccentric position of the nucleus, diffuse staining of the protoplasm with blurring of Nissl bodies, vacuolation, enlargement of pericellular spaces), led to the conclusion that such phenomena must either be due to artefacts or that they were themselves an expression of phases of functional activity.

Experiment III.—Adult black-and-white rabbit. Forty-eight hours. Operation practically bloodless. No inflammation ensued. Fixation in 10 per cent. formol-saline and in Müller's solution. Staining by toluidin blue and Weigert's iron-hæmatoxylin method.

Microscopic examination.—The ganglion cells in both retinæ were frequently profusely vacuolated, and pericellular spaces were well marked. The chromatin granules showed little or no variation from the normal, but the number of atypical cells (*i.e.*, those which show diffuse staining of the protoplasm, vacuolation, &c.) was greater for the operated than for the control eye. The outer layers were unchanged.

Experiment IV.—Adult albino. Seventy-two hours. There was some hæmorrhage early in the operation, which was easily controlled. No inflammation ensued. Fixation in 50 per cent. alcohol. Staining by toluidin blue and hæmalum and eosin. Silver preparations unsatisfactory,

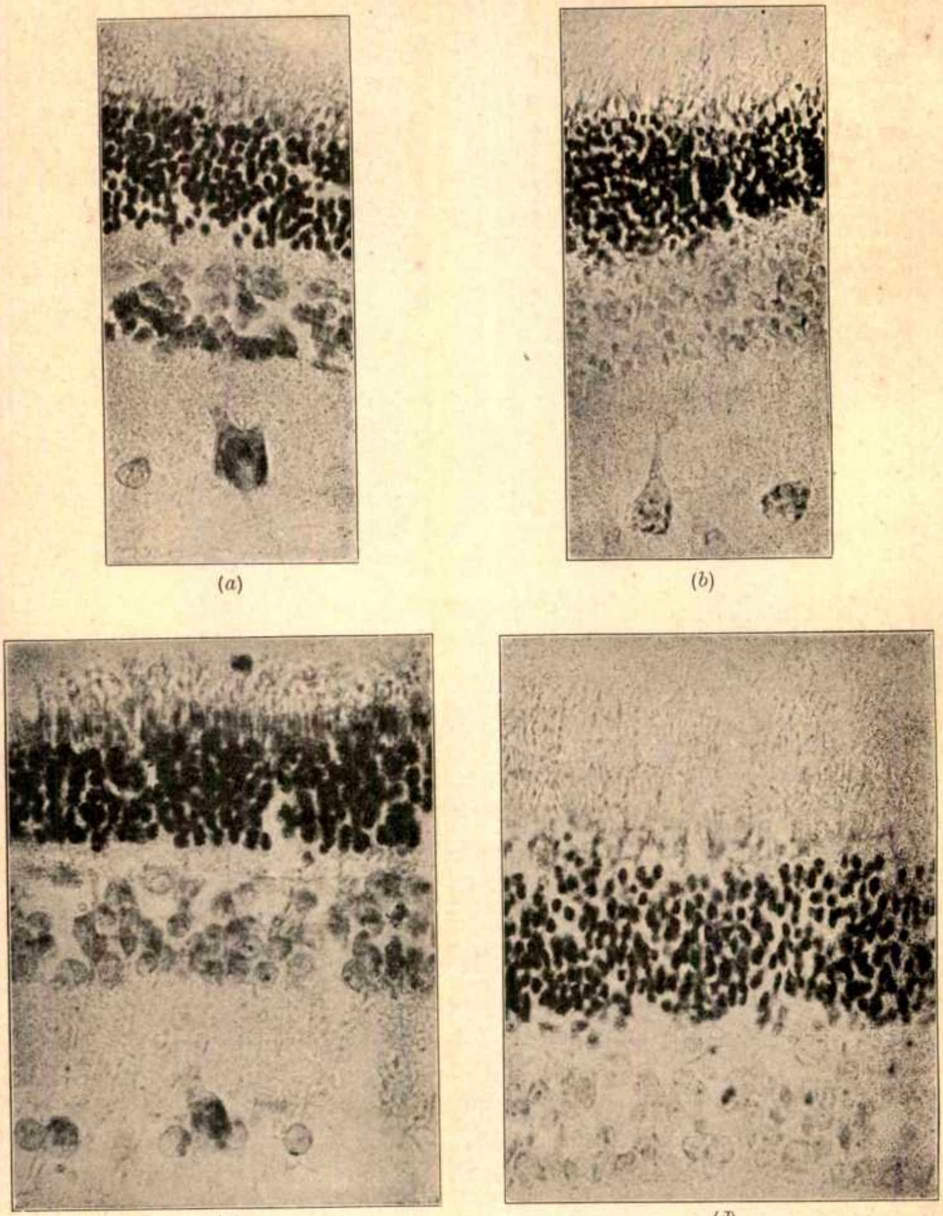
Microscopic examination.—In the sections the line of division was seen to be behind the entrance of the vessels into the nerve. The ganglion cells were on the whole well preserved, some of them showing fairly well defined chromatin bodies. There was, however, evidence of a certain amount of shrinking in the cells of the operated eye as compared with the control. In the cells of the latter there was a clear space around the nucleus, whereas in those of the operated eye this space was often reduced by the shrinking of the cell, so that the cell appeared as a more or less dense ring-like band of chromatin encircling the nucleus. The cells of the outer layers showed no variation from normal.

Experiment V.—Adult black-and-white rabbit. Four days (fig. 2). Operation without hæmorrhage. No inflammation followed. Fixation in 50 per cent. alcohol. Staining with toluidin blue. Silver impregnation successful for the operated, unsuccessful for control.

Microscopic examination.—There was on the whole no great abnormality in the operated retina. There were often tolerably well preserved cells in the ganglionic layer, but definitely "normal" cells occurred only in the control. The outline of the chromatin bodies was not at any time so sharp in the operated eye as it was in the control, and there was evidence of condensation and shrinkage in many of the cells. The other layers were normal. The silver preparations in the operated eye showed numerous fine varicosities in the fibrils of the internal plexiform layer. The broad, ribbon-like bands of the external layer were well demonstrated. The silver preparations of the control also were successful.

Experiment VI.—Adult black rabbit. Seven days. There was slight retrobulbar hæmorrhage at time of operation, and slight transient conjunctivitis ensued. At the time of death the eye appeared normal. Fixation in 50 per cent. alcohol and Müller's solution. Staining by Weigert's iron-hæmatoxylin method and toluidin blue. Silver preparations were successful in both control and operated eye, but no striking difference was revealed by this method.

Microscopic examination.—In the ganglion cells of the operated eye the chromatin granules were small and had a tendency to become



(*a*) (*b*)

(*c*) (*d*)

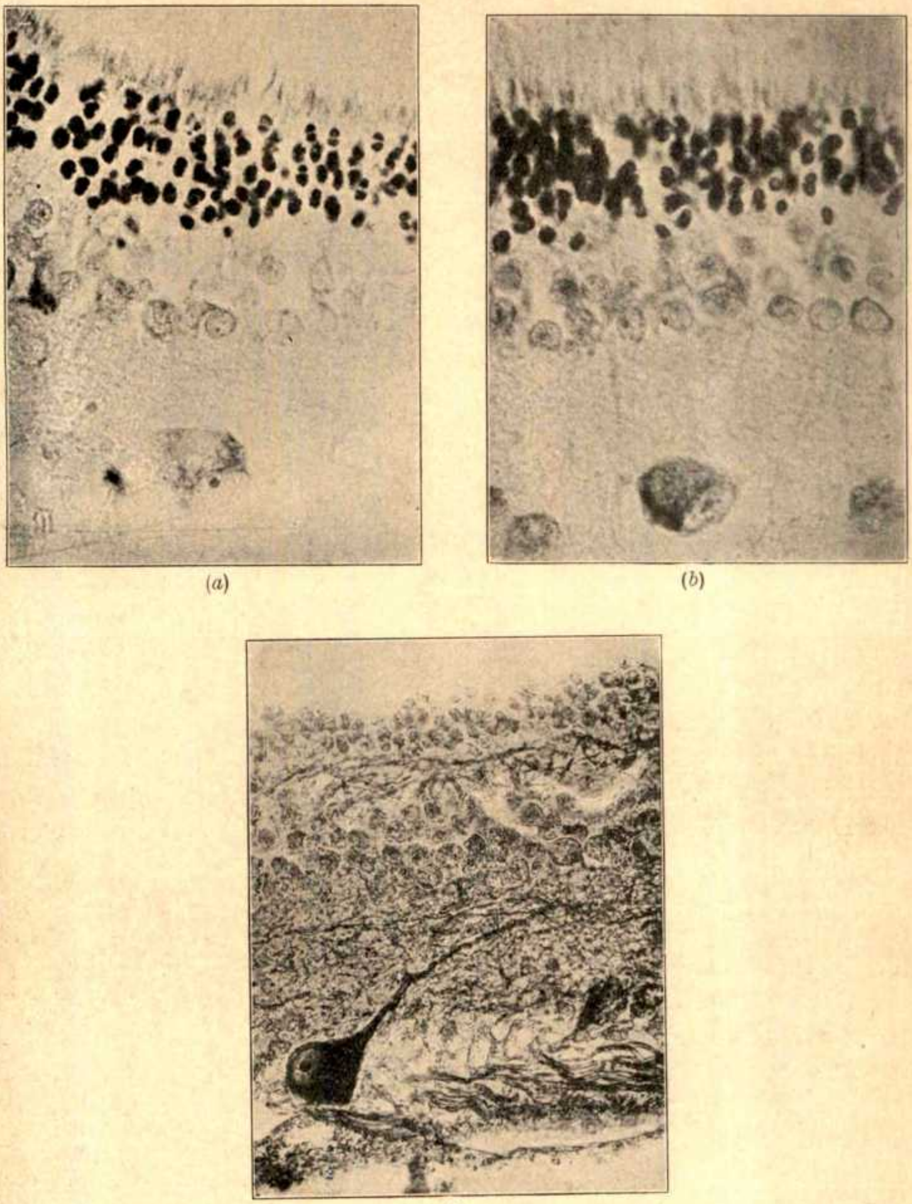
FIG. 2.—Experiment V. Four days after section of the optic nerve.

(*a*) *Operated.* Tol. B. Photomic. × 700. Showing large ganglion cell with somewhat diffuse staining. The outer layers are normal.

(*b*) *Control.* Tol. B. Photomic. × 500. Although under lower magnification than (*a*), the ganglion cells show much greater detail of structure. The outer layers contrast rather unfavourably with those of (*a*).

(*c*) *Operated.* Tol. B. Photomic. × 950. To show normal outer layers.

(*d*) *Control.* Tol. B. Photomic. × 950. Outer layers compare unfavourably with (*c*).



(*a*) (*b*)

(*c*)

FIG. 3.—Experiment VII. Eight days after section of the optic nerve.

(*a*) *Operated*. Tol. B. Photomic. × 1,000. Showing outer layers normal. Note well-marked "cross-striping" and "cog-wheel" in the outer nuclear layer.

(*b*) *Control*. Tol. B. Photomic. × 1,000. Showing outer layers which are, if anything, less "normal" than in (*c*).

(*c*) *Operated*. Silver impreg. Photomic. × 800. Shows large ganglion cell with dendrite passing upwards to inner plexiform layer. The axon becomes continuous with an optic fibre (below).

broken up into fine dust. When the granules were large they had rather badly defined edges. Occasionally large, fairly well preserved ganglion cells were met with, but they were never so large or so well differentiated as the large cells of the control. The other layers were normal.

In the silver preparations the varicosities of the fibrils of the cellular processes were most marked in the operated eye, being almost absent in the control. The processes of the "horizontal cells" of the internal nuclear layer were specially well demonstrated in the control.

Experiment VII.—Adult albino. Eight days (fig. 3). Operation bloodless. Fixation in 50 per cent. alcohol, and in Müller's solution. Silver impregnation successful in the operated eye, failed for the control. Staining with toluidin blue and Weigert's iron-hæmatoxylin.

Microscopic examination.—Well-preserved ganglion cells occurred much less frequently in the operated eye than in the control. The cells of the former were usually pale-staining, with finely divided chromatin. The pericellular spaces were more pronounced in the control than in the operated eye. The outer retinal layers were normal. In the silver preparations varicosities were occasionally met with in the fine fibrils of the inner plexiform layer. The fibrils of the external plexiform layer were seen to end in a rich anastomosis around the cells of the external nuclear layer. The protoplasmic processes of the ganglion cells were devoid of varicosities.

Experiment VIII.—Adult albino. Three weeks (fig. 4). There was slight hæmorrhage during the operation and a corneal ulcer developed. This cleared up, and, at the time of death, a small scar only remained on the otherwise healthy looking cornea. Fixation in 50 per cent. alcohol. Staining with toluidin blue; hæmalum and eosin.

Microscopic examination.—In the control the number of "atypical" ganglion cells in this case was considerable, but at the same time there was a preponderance of typical cells. In the operated eye, on the other hand, one rarely, if ever, met with a typical ganglion cell, the best preserved cell consisting usually of a peripheral ring of small bead-like granules surrounding a densely stained nucleus. The outer layers were normal.

Sections stained with hæmalum and eosin showed the presence of a considerable amount of inflammatory exudate with giant cells around the stump of the optic nerve. It is probable that the pronounced atrophy of the ganglion cells in this case was partly due to the inflammatory conditions and not solely to division of the nerve, although from the fact that the outer layers were unaffected we did not reject the experiment.

Experiment IX.—Adult albino. Three weeks (fig. 5). Operation almost bloodless. No inflammation ensued. Fixation in 50 per cent. alcohol, in a saturated solution of $HgCl_2$, and in 10 per cent. formol-saline. Staining with toluidin blue.

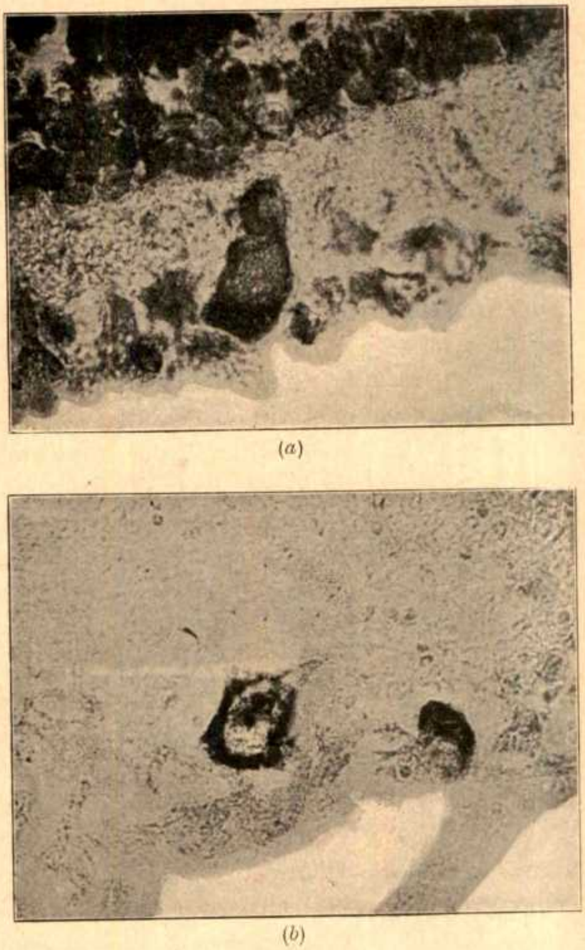


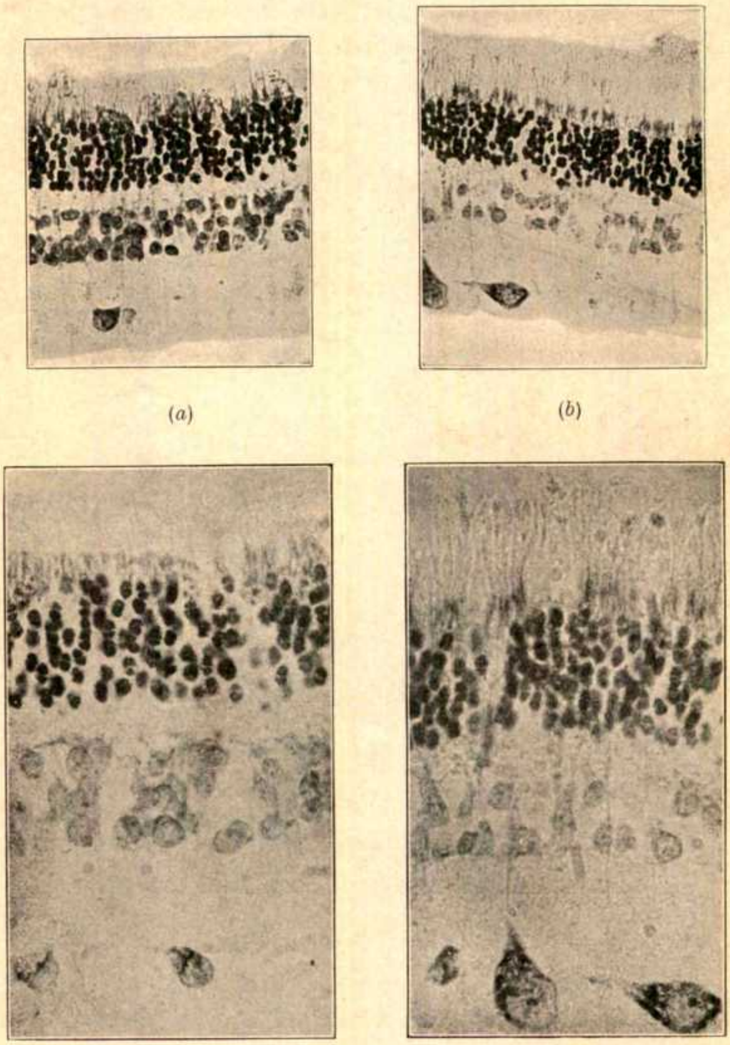
FIG. 4.—Experiment VIII. Three weeks after section of the optic nerve.

(*a*) *Operated.* Tol. B. Photomic. × 1,000. Note the diffusely staining ganglion cell with what appears to be the extruded nucleus (above).

(*b*) *Control* as in (*a*). Large typical ganglion cell in centre; small cell to the right, showing degeneration (eccentric extruded nucleus and rupture of cell).

Microscopic examination.—(i) Tissues fixed in $HgCl_2$. The ganglion cells were smaller in the operated eye than in the control. The Nissl granules were almost entirely absent from the operated eye. Vacuolation and enlargement of the pericellular spaces occurred with no greater frequency in the operated than in the control eye. The outer layers were normal.

(ii) Fixation in 50 per cent. alcohol. There was a general tendency



(a) (b)

(a¹) (b¹)

FIG. 5.—Experiment IX. Three weeks after section of the optic nerve.

(a) *Operated.* Tol. B. Photomic. × 400. Shows small ganglion cells which are somewhat diffusely stained and have feeble processes. The outer layers are normal.
(a¹) Same. × 1,000.
(b) *Control* as in (a). Showing normal ganglion cells, and outer layers.
(b¹) Same. × 900.

to clearer definition in the cells than was the case in fixation with $HgCl_2$, but the same relative differences existed between the two eyes as in the former.

(iii) Fixation in formol-saline. There were appearances of pronounced vacuolation in the ganglion cells of both eyes. The sharpness of intranuclear definition was less than that obtained by employment of either of the preceding methods, but the difference between the ganglion cells of the two retinæ was maintained as in the former.

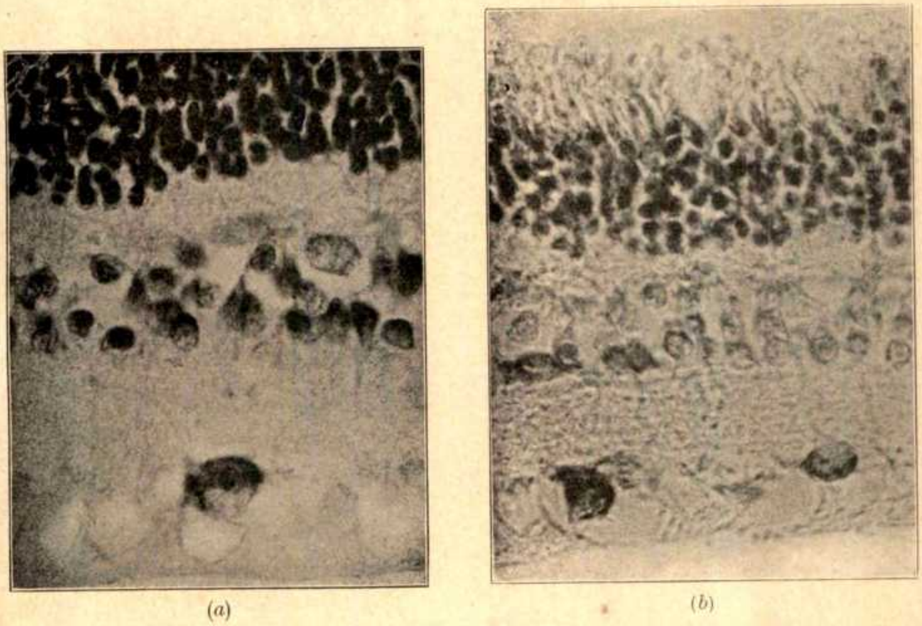

(*a*) (*b*)

FIG. 6.—Experiment X. Six weeks after section of the optic nerve.

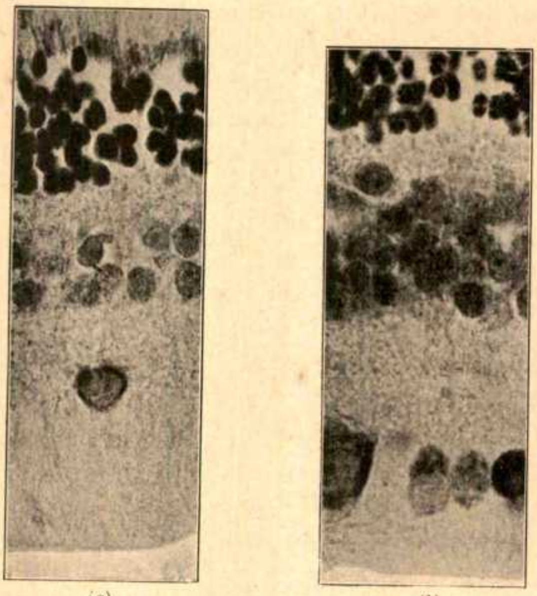
(*a*) *Operated.* Tol. B. Photomic. × 1,000. The ganglion cell in the lower part of the field shows somewhat diffuse staining. The outer layers are practically normal, the nuclei of the rods and cones showing a well-marked "cross-striping" and "cog-wheel" arrangement.

(*b*) *Control.* × 950. To show outer layers with normal appearances.

By the formol-saline method of fixation one saw particularly well demonstrated the cells of the innermost stratum of the internal nuclear layer (? amacrine cells of Cajal) which were arranged at intervals from one another, each cell showing a distinct downgoing protoplasmic process containing chromatin. These cells were slightly more conspicuous in the operated than in the control eye, and were possibly in connexion with centrifugal fibres.

Experiment X.—Small white rabbit. Six weeks (fig. 6). Operation practically bloodless. Slight corneal inflammation ensued which resulted in a small leucoma at the lower part of the cornea. At the time of death the eye seemed otherwise normal. Fixation in 50 per cent. alcohol. Staining with toluidin blue and with hæmalum and eosin. Silver impregnation unsuccessful.

Microscopic examination.—In the hæmalum and eosin specimens the ganglion cells of the operated eye were seen to be much reduced in size. The nucleus was often all that remained to represent the cell. These nuclei were irregular in outline and were very densely stained. In the toluidin blue specimens the cell body was diffusely stained, or the chromatin was in the form of dust-like particles. The cell processes were attenuated and tapered off sharply close to the cell body. The cells of the internal and external nuclear layer appeared normal, except



(*a*) (*b*)

FIG. 7.—Experiment XI. Fifteen weeks after section of the optic nerve.

(*a*) *Operated.* Tol. B. Photomic. × 1,000. Note the solitary ganglion cell having a scanty ring of protoplasm around the centrally situated nucleus. The cells of the inner nuclear layer are normal. The cells of the outer nuclear layer are densely stained and show less definition than in the control, but still show indication of "cross-striping" and "cog-wheel" arrangement.

(*b*) *Control* as in (*a*). Showing deeply stained ganglion cells alternating with others which tend to become rarefied. Note well-defined "cog-wheel" markings of outer nuclear layer. In this case the slides to be photographed were not from strictly the same regions in both, as will be seen from the marked preponderance of ganglion cells in the control, but the points illustrated are borne out in all the other sections examined.

for the fact that occasionally the cone nuclei in the operated appeared somewhat smaller than in the control.

Experiment XI.—Adult albino. Fifteen weeks (fig. 7). There was practically no hæmorrhage during the operation. No inflammation ensued. Fixation in 50 per cent. alcohol, in saturated solution of $HgCl_2$, and in formol-saline 10 per cent. Staining with Weigert's iron-hæmatoxylin and toluidin blue.

Microscopic examination.—(i) $HgCl_2$ fixation. The ganglion cells of the operated eye were very much shrunken, and were diffusely stained. Differentiation into granules was scarcely ever met with, the ground substance being always diffusely stained. Vacuolation when present was less frequent in the operated than in the control eye. Pericellular spaces were not well seen. There was slight impairment of "cog-wheel" marking in the cells of the outer nuclear layer, but "cross-striping" was present. Inner nuclear layer normal.

(ii) Fixation in 50 per cent. alcohol. Occasionally the affected ganglion cells showed indication of granular structure, but at best the granules were small and dust-like. The pericellular spaces were more conspicuous than in (i), and were of less frequent occurrence in the operated eye than in the control. Vacuolation was rarely seen in either. The cells with their processes were on the whole more sharply outlined both in operated and control than was the case in fixation with $HgCl_2$. No abnormality was to be made out in the inner nuclear layer. The outer nuclear layer showed slight loss of "cog-wheel" marking and "cross-striping."

(iii) Fixation in formol-saline. Vacuolation was rather well marked, occurring on the whole with greater frequency in the control. Staining was not so satisfactory for operated or control as in (i) or (ii).

Experiment XII.—Adult albino. Sixteen and a half weeks (fig. 8). There was slight hæmorrhage during the operation. No inflammation ensued. Fixation in 50 per cent. alcohol. Staining with toluidin blue, hæmalum and eosin. Silver impregnation was highly successful in the control, but failed in the operated eye.

Microscopic examination.—The ganglion cells in the operated retina were much shrunken (although no enlargement of the pericellular spaces was visible). "Normal" ganglion cells were entirely absent. Staining was, as a rule, very diffuse, although occasionally a dust-like condition of the chromatin occurred. In the latter case the dust-like particles were met with in the centre of the cell, and were surrounded by a row of somewhat larger bead-like chromatin granules near the cell

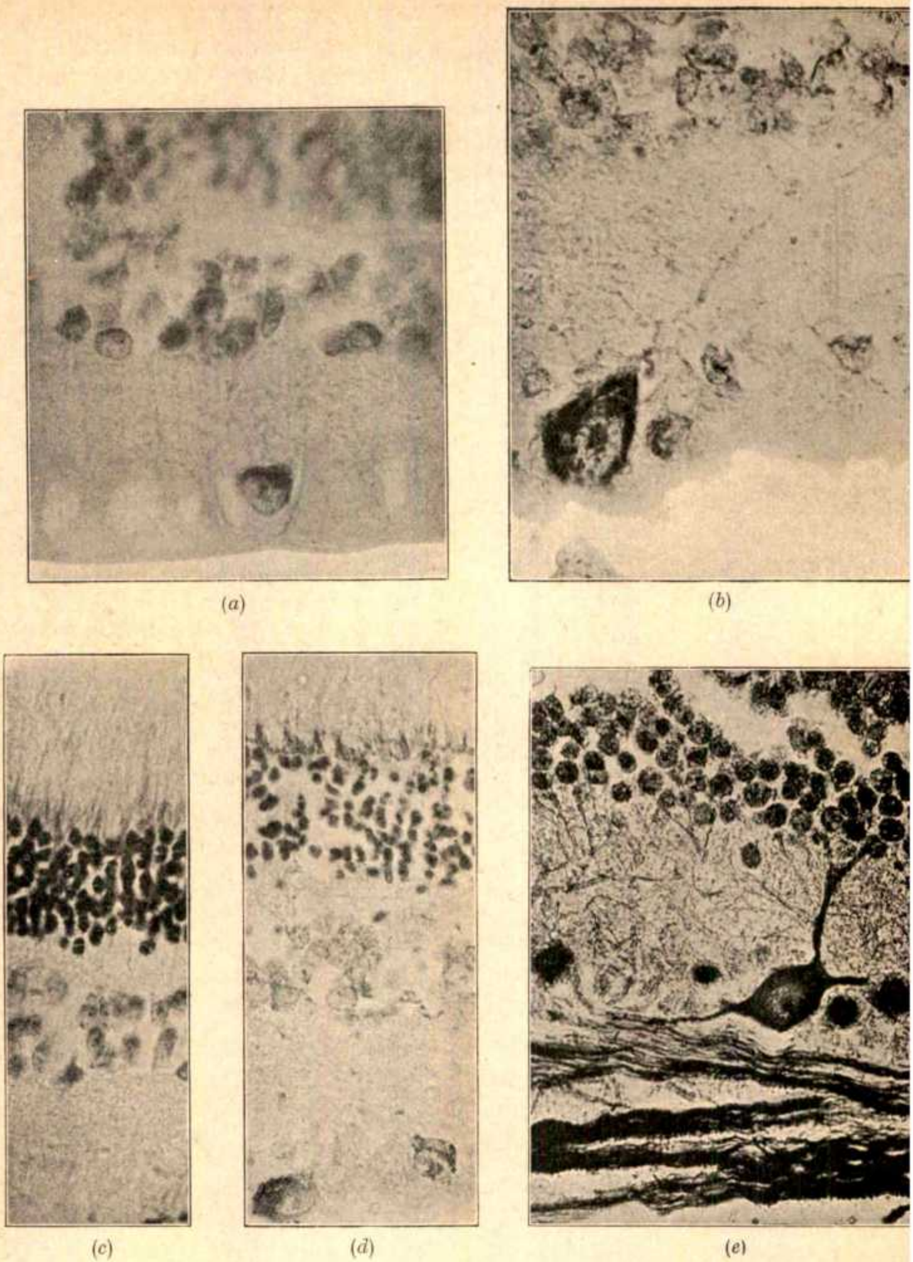


FIG. 8. Experiment XII. Sixteen and a half weeks after section of the optic nerve.

(a) *Operated.* Tol. B. Photomic. × 1,000. Showing shrunken ganglion cell. Tl protoplasm is diffusely stained and the nucleus is somewhat eccentric. The pericellul space is seen. Protoplasmic extensions are scarcely visible (compare (b)).

(b) *Control* as in (a). Showing "normal" ganglion cell, with well-defined up-going proces

(c) *Operated.* Tol. B. Photomic. × 950. Showing outer layers which appear normal

(d) *Control.* Tol. B. Photomic. × 950. Showing outer layers which compa unfavourably with (c).

(e) *Control.* Silver impreg. Photomic. × 700. Showing large ganglion cell with we stained processes. The axon is seen passing out (below) to become continuous with an opt nerve-fibre. No varicosities are evident.

margin. The cell processes were much attenuated, being often unrecognizable. The cells of the internal nuclear layer in the operated eye were perhaps paler than in the control, and the cells which were described (in Experiment IX) as being in connexion with centrifugal fibres (amacrine cells) were particularly definite. The cells of the outer nuclear layer appeared unchanged, except for a slight blurring of the chromatin as compared with the control.

Silver impregnation was successful in the control, and it is to be noted that the fibres of the plexiform layers were devoid of varicosities.

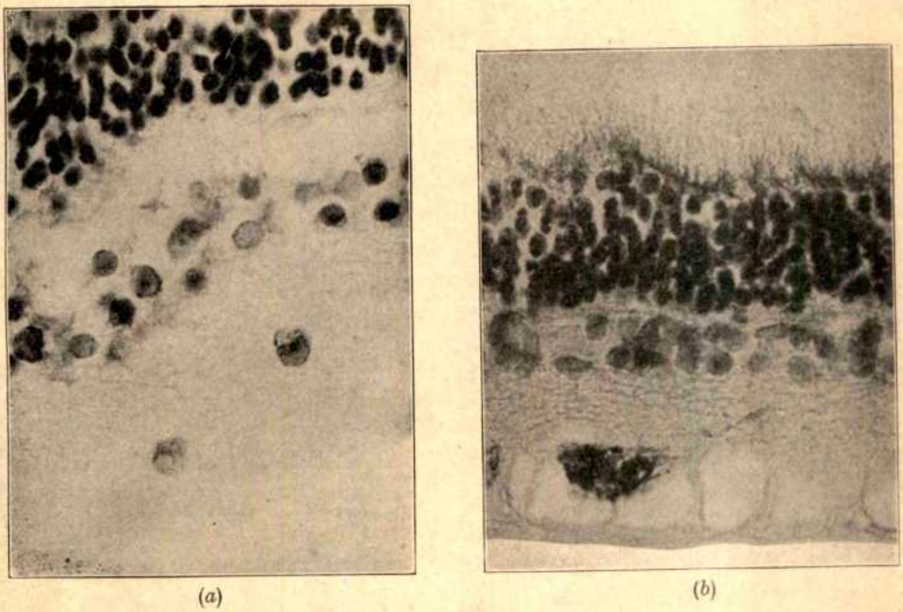


FIG. 9.—Experiment XIII. Thirty-eight weeks after section of the optic nerve.

(*a*) *Operated*. Formol saline fixation. Tol. B. Photomic. × 1,000. Showing shrunken hyaline ganglion cells with eccentric nuclei. The chromatin is diffusely and densely stained. Their pericellular spaces are not enlarged. Note that although definition of the chromatin in the external nuclear layers is not well marked the corresponding elements in the control show similar characteristics.

(*b*) *Control* as in (*a*). Note ganglion cell showing large well-defined Nissl granules. The cells of the outer and inner nuclear layers show scarcely better definition than those of the corresponding layers in (*a*).

Experiment XIII.—Long-haired adult grey rabbit. Thirty-eight weeks (fig. 9). Operation was practically bloodless. Fixation in $HgCl_2$ and 50 per cent. alcohol. Silver impregnation was unsuccessful. Staining with toluidin blue and Weigert's iron-hæmatoxylin.

(i) $HgCl_2$ fixation. In the case of the control beautiful fixation of the ganglion cells was obtained by this method, the Nissl granules being plumper and slightly less well defined than in alcohol fixation. At some parts of the operated retina the ganglion cells were non-existent. At other parts of the retina they were represented, but only by small cells diffusely stained, with eccentric nuclei; or by paler cells with fine dust-like particles of chromatin. The processes of these cells were tapering and ended off sharply close to the cell. The internal nuclei were well preserved. "Amacrine" cells were not conspicuous in these specimens. The cells of the external nuclear layer showed evident "cross-striping" and "cog-wheel" arrangement, and appeared almost normal.

(ii) Formol-saline fixation. Vacuolation was very pronounced, especially in the ganglion cells of the control. Pericellular spaces were no less pronounced in the control than in the operated eye. The ganglion cells in the operated eye were almost universally shrivelled and diffusely stained. Occasionally a large ghost-like cell was met with. Owing to somewhat pale staining of the cells of the internal nuclear layer the "amacrine" cells were often conspicuous. The cells of the external nuclear layer were often lacking in the typical features of cog-wheel marking and cross-striping, but as the same characteristics were met with in the control the defect was probably one of fixation only.

Note.—Of the other experiments performed in this series, three were rejected on account of severe hæmorrhage at the time of operation, the nerve having been divided of necessity rather blindly owing to difficulty in isolating it from the adjacent structures. Two experiments ended in phthisis bulbi. Three cases were discarded on account of unsatisfactory fixation (picro-formol) and eight were lost through the occurrence of incidental disease in the rabbits.

(*iv*) *Discussion of Results.*

A numerical estimate of the cells of the ganglionic layer in the case of the operated eye as compared with the control appeared to be of some value in forming an idea of the proportion of ganglion cells which had perished in the course of the experiment. The method of carrying out the attempt was the following:—

(1) As nearly as could be accomplished the same part of the retina was taken for control and operated eye.

(2) Owing to the difficulty in arriving at an idea of what were cells in a state of perfect preservation as compared with others less well

preserved, the plan was adopted of including all the ganglion cells which were present and could be recognized as such, with a view to finding if there were reduction in their number in the operated eye.

(3) Estimation was made by means of the eye-piece micrometer, the lineal unit being ·2 mm., with ultimate calculation for 1 mm.

Thus we see that throughout the series a considerable reduction was the rule, a reduction which was a confirmation of the descriptive results given in the text. That some disappearance of cells had taken place is to be assumed from a scrutiny of the table given above. When degeneration of the ganglion cells took place the first to disappear were the smallest cells. These cells were not always distinguishable from the other cells of the ganglion and nerve-fibre layer, and even from small inflammatory cells (lymphocytes), so that in the early cases one may find somewhat conflicting results—*e.g.*, in Experiment IV, in which an increase in cells was obtained. This increase may be explained

TABLE.

No. of experiment	Duration	Number of fields examined		Average cells per ·2 mm.		Average per 1 mm.		Average per 1 mm. in round numbers		Descriptive result in operated eye
		Control	Operated	Control	Operated	Control	Operated	Control	Operated	
i.	24 hours	89	89	2·78	2·74	13·9	13·7	14	14	No material difference.
ii.	48 ,,	45	45	9·20	4·28	46·5	21·4	46	21	Much fewer.
iii.	48 ,,	40	40	3·52	3·70	17·6	18·5	18	18	No change, or slightly more numerous.
iv.	72 ,,	30	30	2·23	3·33	11·1	16·6	11	17	Much more numerous.
v.	4 days	52	52	12·56	4·32	62·8	21·6	63	22	Much fewer.
vi.	7 ,,	60	60	2·30	1·82	11·5	9·1	11	9	Fewer.
vii.	8 ,,	64	64	6·48	5·29	32·4	26·4	32	26	Fewer.
viii.	3 weeks	43	43	8·41	1·93	42·0	9·6	42	10	Much fewer.
ix.	3 ,,	523	523	4·56	3·62	22·8	18·1	23	18	Fewer.
x.	6 ,,	30	30	3·53	2·43	17·6	12·1	18	12	Fewer.
xi.	15 ,,	1,023	1,023	3·85	3·04	19·2	15·2	19	15	Fewer.
xii.	16½ ,,	30	30	2·50	2·06	12·5	10·3	12	10	Fewer.
xiii.	38 ,,	482	482	6·10	2·83	30·5	14·1	30	14	Much fewer.
					Aggregate			339	206	

Note.—(i.) Out of an aggregate of 339 for the control, and 206 for the operated eye, the average in each of the 13 cases may be taken as 26·7 and 15·84 respectively (indicating a marked reduction for the operated eye).

(ii.) The variability in the control ranges from 63 as highest to 11 as lowest, whereas in the operated eye the range is only from 26 to 9.

(iii.) In the control 5 are above 26·7, in the operated eye all are under 26·7. In the control 4 are under 15·84, in the operated eye 7 are under 15·84.

by the fact that the region of retina examined in the operated eye was not strictly analogous to that of the control. In the later cases where there was less probability of the presence of inflammatory cells, whatever error there might be in the inclusion of extraneous cells was lessened, but always one was inclined to make one's enumeration somewhat larger than the actual, owing to the difficulty of differentiating degenerated ganglion cells from small neuroglial nuclei and lymphocytes.

In the case of the control, however, such confusion was not met with, since the ganglion cells were better defined and more easily distinguished. In this way the numerical results may be taken as somewhat *under-estimated*, so that the reduction obtained in the retina of the operated eye was even more substantial than it appears.

Thus we see that as early as forty-eight hours after operation certain changes in the ganglion cells were to be recognized. These changes consisted in a loss of perfect definition in the chromatin granules, probably due to the fact that the ground substance of the cell had taken up the stain to a slight extent. Degeneration apparently did not progress with extreme rapidity, the condition not being much more pronounced at eight days than at forty-eight hours. This is of significance when compared with the early chromatolytic changes described by Nissl and others, in case of peripheral nerve section. At three weeks, however, degeneration was definite and became more pronounced with the lapse of time, till at thirty-eight weeks (the longest time allowed) degeneration was practically complete.

Owing to the large range of variability shown by the retinal ganglion cells in the control eyes, one is diffident about drawing conclusions regarding the significance of the so-called "phenomena of degeneration." Adopting, however, as normal the appearances which in the control occurred with the greatest frequency, one endeavours to estimate not only the frequency with which the frankly abnormal types occur in the operated eye, but also (which is of more importance) to determine whether or not it contains "normal" cells.

Degeneration apparently attacks the medium and small cells at an early stage, and my observations were throughout the investigation chiefly confined to the largest ganglion cells. The smaller cells are especially liable to accident in the course of histological preparation, and are frequently of abnormal appearance even in the control. In any case, one must neglect the condition obtaining in the smaller cells, as there is difficulty in recognizing the gradual changes in any but the largest ganglion cells. The type of normal cell, therefore, with which one makes comparison is the large multipolar ganglion cell in which the Nissl granules of various sizes are sharply stained, and are arranged in somewhat concentric rows around the more or less central nucleus. The nucleus contains numerous chromatin granules and one or more nucleoli. The ground substance of the cell body is unstained. Granules of chromatin are to be found for a considerable distance along the protoplasmic processes, and vacuoles may or may not occur. With regard to the occurrence of vacuoles, Birch-Hirschfeld emphasizes the fact, that in his cases vacuolation was confined entirely to the operated eye. In the present series, vacuolation was never more conspicuous in the cells of the operated than in those of the control eye—in many cases less so.

In recapitulating, therefore, one finds as the result of optic nerve section, that degeneration has set in as early as forty-eight hours, and is evidenced by the absence of entirely normal ganglion cells. Degeneration advances steadily and is estimated by the complete absence of normal cells, as well as by the progressive increase in the number of frankly abnormal or degenerated cells. At a period of thirty-eight weeks almost all the cells are atrophic.

Passing from the above degeneration of the sensory neurone of the higher or second order, one comes to a consideration of the fate of the more peripheral and independent neurones of the first order situated in the outer retinal layers. Judging from all authoritative accounts, the neurones of the retinal layers are in intimate relationship with one another. Birch-Hirschfeld described well-marked changes in the nuclear layers, as result of optic nerve section. These changes consisted, in the case of the inner nuclear layer, of reduction in size, irregularity of outline of the cell, and condensation of chromatin. The cells of the outer nuclear layer showed rounding of cells, reduction in the size of the interspace tending to obliteration of the "cross-striping," and loss of chromatin of edges ("cog-wheel" markings).

In the present series no essential changes in these layers could be made out. In some cases pale staining of the inner nuclei, or dense staining of the outer nuclei with slight loss of definition might be described, but these conditions are manifest in the control with so much frequency that their occurrence often appears to be due to differences of intensity of stain, rather than to pathological factors. In fact, one is often able to demonstrate from one slide in the control differences of staining which, if they were to occur in the operated eye, might be looked upon as significant. The fact, however, that Birch-Hirschfeld mounted the corresponding sections from the two eyes upon the same slides probably eliminated error in this direction to a large extent.

More positive features than differences of staining power are those of *reduction in size*, *irregularity of outline*, and *loss of the discrete nature of the chromatin granules*. In the present series practically no evidence of such changes in the outer neurones was to be made out. One may, therefore, assume with fair confidence that the integrity of the outer neurones in these experiments has been preserved, and that the operation of section of their axon which produced serious damage in the case of the higher neurone (connecting the organ with central nervous system) was accomplished by little or no disturbance of the contiguous peripheral neurones. The slight loss of definition met with in the outer neurones in Experiment XI is compensated for by the absence of this feature in Experiment XIII (a much later period).

Having thus established the point that the peripheral neurones remain intact for such prolonged periods after separation from the central neurones, the question arises whether they are *intrinsically* more resistant than the outer neurones. To determine this, it was decided to study the progress of *post-mortem* changes in the retinal neurones.

B. Results of Autolytic Experiments.

(*i*) *General Remarks.*

Most of the previous work done upon *post-mortem* changes in nerve-cells has been concerned with the *post-mortem* changes in ganglion cells of the brain and cord. In the following experiments the changes occurring in the retinal neurones were investigated.

Birch-Hirschfeld [8] described *post-mortem* changes in the ganglion cells of the retina. He used the sublimate-thionin method and found evidence of change as early as two hours after death. There was slight folding of the nuclear membrane and loss of definition in the Nissl granules. The outer nuclear layer showed rounding off of the nuclei, especially of the rods, with commencing loss of "cross-striping" and edge crenation. After three and a half hours the ganglion cells showed enlarged vacuoles, especially at the periphery of the cell. The chromatin was still more or less in the form of granules. The nuclei of the internal nuclear layer were partially degenerated. There was no evidence of "cross-striping" in the nuclei of the external nuclear layer. After five hours there was deep staining of the ground substance with blurring of the nuclear and cell-outline. After seven hours the Nissl granules had disappeared and the ground substance no longer stained deeply. The nucleus had practically vanished. The outer nuclear layer showed rounding of its nuclei with here and there a hint of "cross-striping." After eighteen hours the changes had progressed further and little or no chromophilic substance remained.

In the foregoing experiments it is not clear whether some of the changes described were not due to putrefactive conditions. In the present series, in order to eliminate as far as possible the influence of micro-organisms occurring in the surroundings, the following method of examination was adopted. The enucleated eyeball having been thoroughly cleared of all extrinsic structures (muscles, fat, &c.), so that a smooth contour might be obtained, the shortened stump of the optic nerve was grasped in forceps and the eyeball was plunged into melted paraffin (52° C.) for a few seconds. The thin layer of paraffin which adhered to the surface of the eyeball rapidly congealed, and the naked nerve was easily covered by a drop of paraffin poured on its surface. In this way the eyeball was sealed from the atmosphere by a layer of sterile material. The changes, therefore, which would take place within the eyeball were presumably those of *autolysis* and not *putrefaction*. The "enveloped" eyes were allowed to stand at room temperature (or in one or two cases at incubator temperature) for the desired period. When this had elapsed the layer of paraffin was easily chipped off and the eyeball treated henceforth in the same manner as the control. In the cases in which ox-eyes were used, the eyeballs were obtained from the slaughter-house with as little delay as possible, and could be looked upon for all practical purposes as fresh. In the case of the other animals (dog, cat, rabbit) the eyes were obtained in the laboratory and fixation took place immediately after the death of the animal.

(*ii*) *Experimental Details.*

Experiment I.—Ox-eye. Autolysis for sixteen hours at room temperature. Fixation in picro-formol solution (a fixative which was successful in the case of the ox-eye although less satisfactory in the delicate rabbit retina).

Sections stained by Weigert's iron-hæmatoxylin method showed much disorganization of the rods and cones. The "palisade" arrangement of this layer was almost unrecognizable. Under low magnification the other layers of the retina appeared unchanged when compared with the control. The external and internal nuclear layers were intact and separated from one another by the outer plexiform layer (which was of apparently normal thickness). Under higher magnification the cells of the external nuclear layer were seen to be densely stained and somewhat smaller than normal. The "cog-wheel" arrangement (Nissl staining) was still recognizable. The cells of the internal nuclear layer showed a reticulum in the form of more or less radiating strands around the deeply stained central nucleolus, and were on the whole slightly less sharply defined than in the control. The innermost cells of this layer ("centrifugal cells") with their downward passing processes were somewhat densely stained and stood out in strong contrast to the more feebly stained cells in the rest of the layer. The cells of the ganglionic layer were tolerably well preserved. Their processes stood out distinctly and the nuclear reticulum was well defined.

There was some blurring of the edges of the chromatin granules of the ganglion cells when stained with toluidin blue. The fibres of Müller stood out distinctly both as regards their nuclei and their fibrous expansions in the nerve-fibre layer.

Taken as a whole the changes which occurred in the ox-eye as the result of autolysis for sixteen hours are not fairly marked and resolve themselves into :—

(1) Disorganization of the rods and cones.

(2) Slight reduction in size of the rod and cone nuclei with a tendency to diffuseness of staining, although the "cog-wheel" appearance was still manifest.

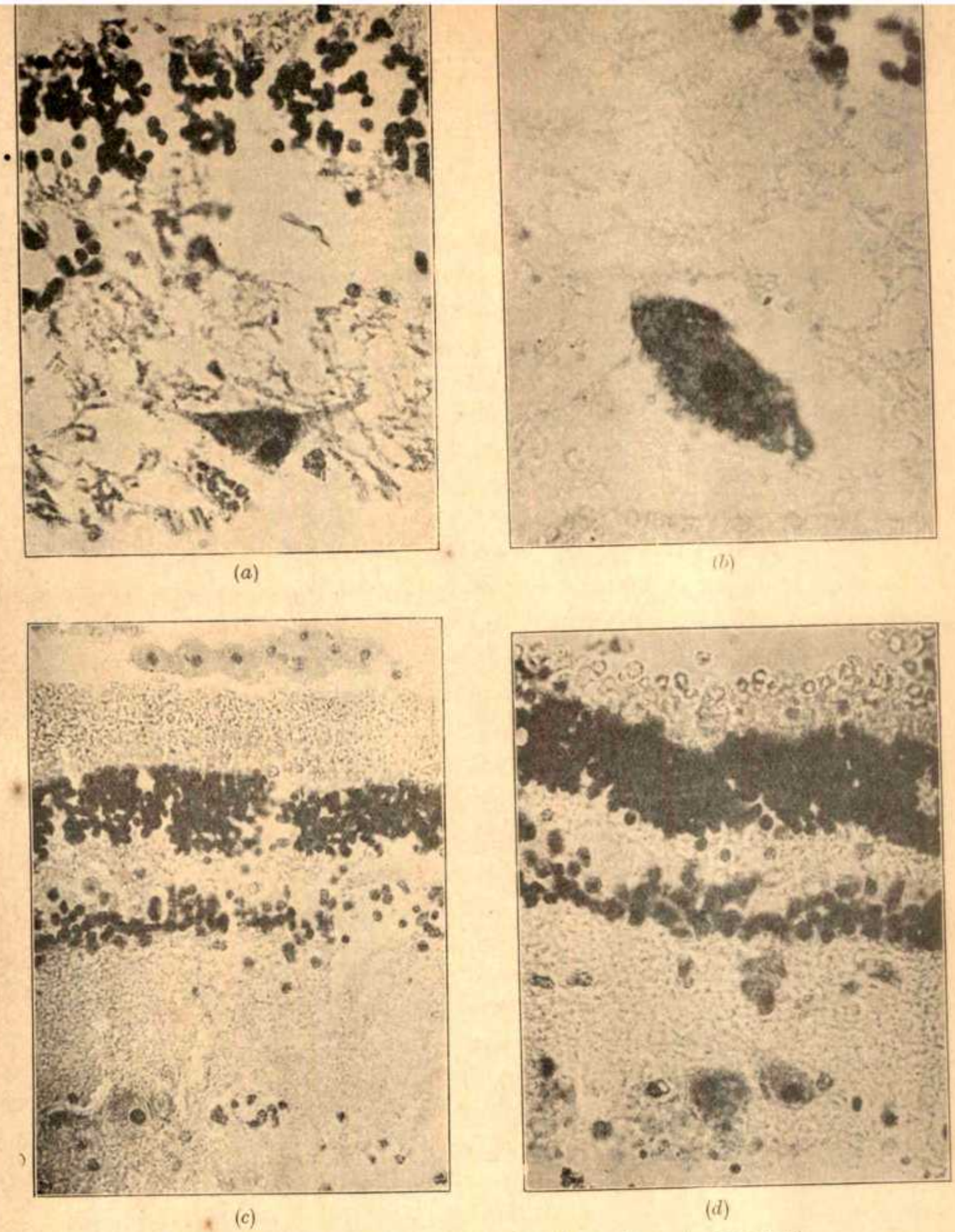
(3) Slight loss of prominence in the cells of the internal nuclear layer, with prominence of Müller's fibres and the centrifugal cells of the layer.

(4) Slightly increased prominence of the protoplasmic expansions of the ganglion cells which are thrown into relief by the commencing disorganization of the ground substance of the retina.

Experiment II (fig. 10).—Ox-eye. Autolysis for twenty-four hours (room temperature).

A. Fixation in 50 per cent. alcohol. Staining by Weigert's iron-hæmatoxylin and toluidin blue.

Under a low power the layers of the retina still appeared separate from one another. Under higher magnification the rods and cones were distinctly disorganized although a "palisade" formation was



(a) (b)

(c) (d)

FIG. 10.—Ox-eye, autolysis twenty-four hours (room temperature).

(a) *Autolytic eye.* Fixation in 50 per cent. alcohol. Hæmalum and eosin. Photomic. × 700. Large ganglion cell showing granular condition of the chromatin. The nucleus is somewhat eccentric. The protoplasmic processes are prominent. The cells of the external and internal nuclear layers are considerably more degenerated than the ganglion cells.

(b) *Autolytic eye.* Fixation in 50 per cent. alcohol. Tol. B. Photomic. × 1,000. Large ganglion cell with slight erosion of the cell margin. There is still a fair degree of granular differentiation, but the staining tends to be more diffuse than in control. The nucleus is deeply stained and is central. Protoplasmic processes not indicated.

(c) *Autolytic eye.* Fixation in $HgCl_2$. Hæmalum and eosin. Photomic. × 500. The nuclear layers are still separated from each other by the outer plexiform layer. The cells of the nuclear layers are shrunken and densely stained. The ganglion cell to the left and below is somewhat ghost-like. The rods and cones have lost their "palisade" structure.

(d) *Autolytic eye.* Fixation in $HgCl_2$, Tol. B. Photomic. × 700. Note the dense staining in the somewhat shrunken cells of the outer and inner nuclear layers. The ganglion cells tend to become diffusely stained.

still suggested. The nuclei of the external nuclear layer showed a fair amount of detail, but there was a tendency to blurring of the edges and loss of "cog-wheel" marking.

The internal nuclei showed a well-defined chromatin network, but there was a tendency to enlargement of the spaces between the threads and a general "rarefaction." Many of these spaces appeared full of fat. The nuclei of Müller's fibres were deeply stained. The ganglion cells, both in the iron-hæmatoxylin and toluidin blue preparations, showed commencing degeneration. There was erosion of the inner aspect of the cell, and clear fat-like bodies could be discovered in many. There was a tendency to diffuseness of staining, and the Nissl granules had commenced to coalesce. The processes were not so well marked as in Experiment I (picro-formol fixation).

B. In another specimen fixed (i) by $HgCl_2$ (sat. sol.) and stained by toluidin blue, practically the same appearances were obtained, viz.: the ganglion cells were pale, and showed eroded inner margins; the cell processes were not well defined; the nuclei were well preserved; the outer and inner nuclear layers were not much changed; the rods and cones, however, were much disorganized.

(ii) In the part of the same retina fixed in 50 per cent. alcohol the ganglion cells showed rather more shrinkage and diffuse staining than existed in (i). The external and internal nuclear layers were approximated owing to the collapse of the outer plexiform layer, and the cells of these layers showed diffuse staining.

The discrepancy which exists between B. (ii) and A. may be explained by the fact that in the former a somewhat longer interval had elapsed before the eye was transferred to the laboratory, and that *post-mortem* changes had already set in. The difference between B. (i) and B. (ii) probably lies in the fact that, whilst fixation in the one case was procured by means of $HgCl_2$, in the other it was by alcohol. The latter reagent, in our experience, is the most satisfactory fixative for the Nissl method in fresh tissue, but in the autolytic retina, where the ground substance is unduly fragile and liable to shrinkage, the unfavourable effect of alcohol as a fixative is more pronounced than is the case in fresh, resistant tissues.

C. Another example of autolysis after twenty-four hours showed still more pronounced changes in the outer layers—the differentiation between the outer and inner nuclear layers having become lost owing to the almost complete disappearance of the outer plexiform layer. The ganglionic cells, however, exhibited practically the same features as in the other specimens.

Experiment III (fig. 11). — Ox-eye. Forty-eight hours (room temperature). Fixation in picro-formol solution. Staining in toluidin blue.

In the autolytic retina the layers were seen to be well differentiated, the plexiform layers being still recognizable. The layers of rods and cones, however, were entirely devoid of palisade structure. The external nuclei were densely stained, but there was still indication of the chromatin network ("cog-wheel"). The cells of the internal nuclear layer also were deeply stained, and the details of structure were much more obscure than in the corresponding cells of the control. The ganglion cells showed well-defined, diffusely stained processes, which stood out against the surrounding tissue. The Nissl granules which were to be observed in the control were sometimes scarcely indicated in the autolytic retina, their place being taken by diffusely stained cell-contents.

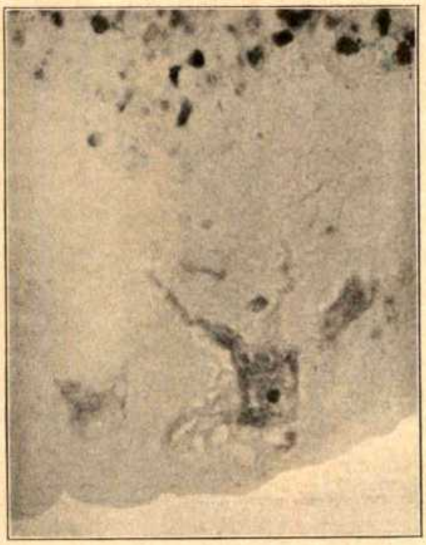
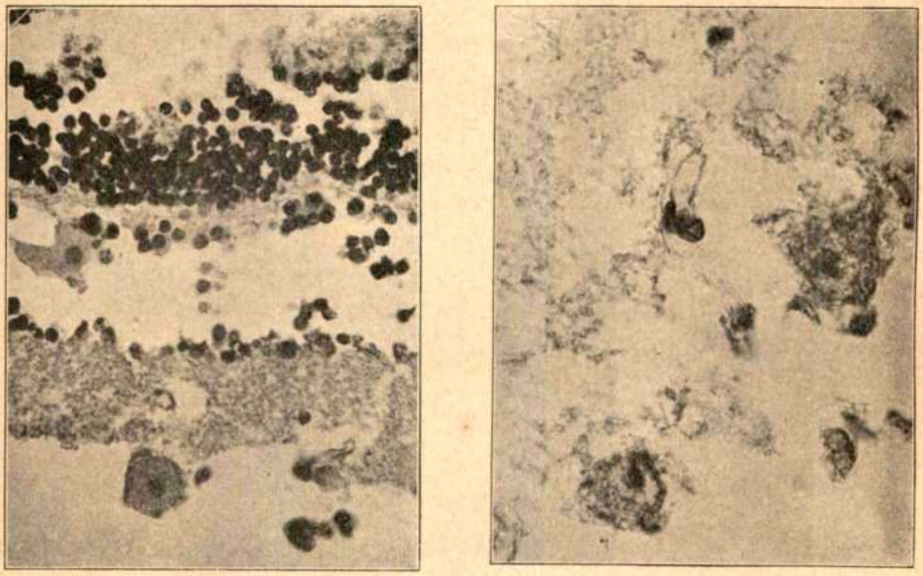


FIG. 11.—Ox-eye. Autolysis forty-eight hours (room temperature).

Autolytic eye. Fixation in picro-formol. Tol. B. Photomic. × 1,000. Large ganglion cell with conspicuous processes and well-defined Nissl granules. Nucleus and nucleolus still well preserved.

Preservation of the ganglion cells in this specimen was on the whole little inferior to that in Experiment II, a fact which showed that autolysis, even after forty-eight hours, had produced marvellously little change in the ganglion cells.

Experiment IV.—Ox-eye. Autolysis for twenty-four hours at 37° C. The "enveloped" eye was placed in the incubator for twenty-four hours, after which fixation was carried out (at room temperature) in picro-formol solution. The control was left in picro-formol for twenty-four hours in the incubator, after which it was treated at room temperature. Staining was by Weigert's iron-hæmatoxylin method. In the control, by the picro-formol method, the rods and cones are well defined. The external nuclear layer showed the usual chromatin reticulum ("cog-wheel," &c.). The nuclei and processes of the ganglion cells were well stained, and the retinal vessels with their capillaries passing obliquely across the inner layers were particularly well demonstrated.



(*a*) (*b*)

FIG. 12.—Ox-eye. Autolysis seventy-two hours (room temperature).

(*a*) *Autolytic eye.* Fixation in Müller's solution. Weigert's iron hæmatoxylin. Photomic. × 500. The external plexiform layer is almost obliterated. The cells of the outer and inner nuclear layers are degenerated (shrunken, densely stained). Large ganglion cell at lower part of field shows somewhat eroded edges and densely stained nucleus.

(*b*) *Autolytic eye.* Fixation in 50 per cent. alcohol. Hæmalum and eosin. Photomic. × 1,000. Ganglion cells with erosion of cell margins, but otherwise fairly well preserved.

In the autolytic retina the rods and cones as such were no longer recognizable. The external nuclear layer was very much broken in outline, encroaching frequently upon the internal nuclear layer. The cells of the former were very deeply stained, and exhibited practically no detail of structure. They were small and globular, and the "cog-wheel" marking was absent. The internal nuclei showed a fair amount of structural detail, but were considerably less well preserved than those of the control. The ganglion cells showed erosion of their inner edges. The nuclei were densely stained, and there was a general tendency to deposition of fat in the form of fine globules. The cell processes were conspicuous. Müller's fibres were reduced to the form of granular masses, their nuclei being densely stained and devoid of detail.

Thus we find in this experiment that subjection to heat has hastened the process of autolysis to a certain extent. The condition of the supporting structures is as much advanced as is the case in autolysis for forty-eight hours at atmosphere temperature (as evinced by the condition of Müller's fibres), and the degeneration of the nerve-elements is likewise much in advance of the condition found in autolysis for twenty-four hours at the lower temperature.

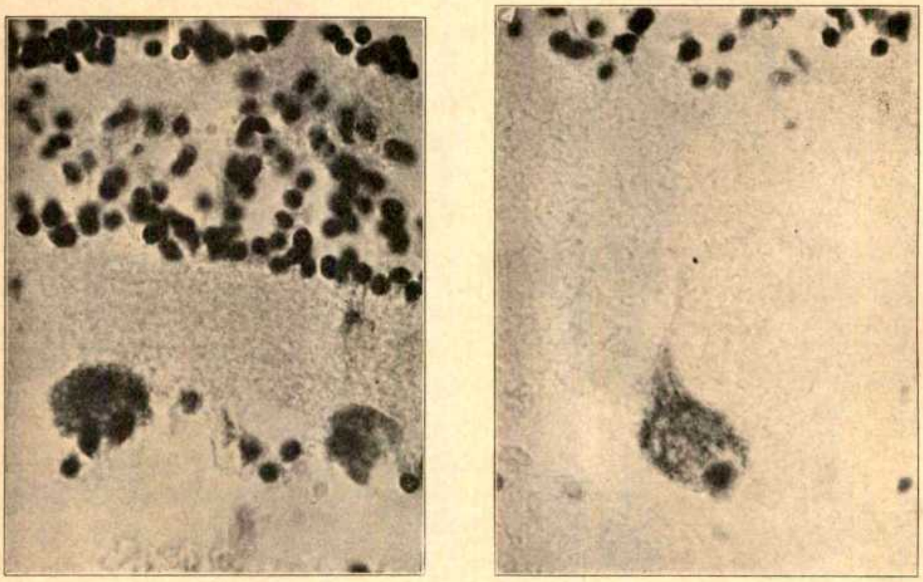
Experiment V (fig. 12).—Ox-eye. Autolysis for seventy-two hours at room temperature.

Fixation in Müller's fluid. No control preparation. The rods and cones were reduced to an amorphous *débris*. The retinal elements were fairly well differentiated into layers, but there was encroachment of the external nuclear layer inwards at places. The nuclei of this layer being circular, small and densely stained, were devoid of all detail ("cog-wheel," &c.).

The cells of the internal nuclear layer were not well differentiated, only here and there exhibiting an indication of the usual chromatin network. The nuclei of the blood capillaries were to be seen at places throughout the inner layers. The nerve-fibre layers showed some traces of fibrous structure. The ganglion cells had resisted and exhibited very fair nuclear structure. (The granules of the cell body were not brought out well by the fixative.) Vacuolation (? fat-globules) was present in many of the cells. Müller's fibres were scarcely visible.

Experiment VI (fig. 13).—Ox-eye. Autolysis for ninety hours at room temperature. Fixation in 5 per cent. alcohol. Stained by toluidin blue, and by hæmalum and eosin.

The external and internal nuclear layers were more or less fused together, and the normal stratification of the retina was often lost to view. It was not always easy to determine the layer to which the various cells belonged, since the cells of the nuclear layer had lost all internal detail, and appeared merely as small round spherical homogeneous bodies. The ganglion cells were still recognizable, and under low magnification appeared to show fairly good preservation. They were, however, more rounded in outline than normal, the processes having almost entirely disappeared. The nuclei were often eccentric and were densely stained. Under high power the ganglion cells were seen to contain numerous fat-globules, the whole cell having a "stippled" appearance. There was occasional evidence of Nissl granules, but these bodies, when present, were blurred and washed out at the edges. Occasionally a long distorted dendritic process was seen in the degenerated ground substance. Here and there one found a well-preserved nucleus showing the typical chromatin network, the cell body of which was almost absent. Erosion apparently always began on the inner aspect of the ganglion cell. The capillary framework was in many places particularly well demonstrated, the vessel walls apparently persisting for a considerable time.



(*a*) (*b*)

FIG. 13.—Ox-eye. Autolysis ninety hours (room temperature).

(*a*) *Autolytic eye.* Fixation in 50 per cent. alcohol. Tol. B. Photomic. × 1,000. Showing fusion of external and internal nuclear layers (the cells of the two layers are scarcely distinguishable from each other). Ganglion cells densely stained, but still showing indication of granules. The nuclei are deeply stained.

(*b*) *Control of* (*a*). Large ganglion cell with strong up-going process. The nucleus is eccentric. Nissl granules lack perfect definition.

In this experiment autolysis had been allowed to go on longer than in any of the others. We find in it that collapse of the outer layers is almost complete; persistence of the innermost layers (ganglion and nerve-fibre layer) is marked. Degeneration of all the "supporting" tissue evidently occurred before that of the true nerve-elements, a point which emphasizes the differentiation between these structures. Degeneration occurred from the periphery of the cell inwards, the processes and cell body disappearing in many cases when the nucleus and central portion of the cell were tolerably intact. The cases in which the processes of the ganglion cells were conspicuous were to be explained by the fact that the ground substance being much degenerated, the comparatively resistant ganglion cells showed up with marked distinctness.

Experiment VII.—Rabbit-eye. Autolysis for eighteen hours at room temperature. Fixation in 5 per cent. alcohol. Stained with toluidin blue.

The rods and cones were no longer recognizable, having entirely lost their "palisade" arrangement. Müller's fibres were prominent. The cells of the external nuclear layer were densely stained, but often showed chromatin network ("cog-wheel" marking and "cross-striping"). The nuclei of the internal nuclear layer were "rarefied," the chromatin threads being attenuated and the interspaces enlarged. The ganglion cells showed well-marked Nissl granules, but there was a blotchiness of the granules, especially of those at the periphery of the cell. There was a ragged appearance of the cell margins, which was not—as was the case in the ox—chiefly confined to the inner aspect. The nuclei of the ganglion cells were somewhat densely stained, at others they were "rarefied," with only an indication of the normal structure. On the whole the retina was well preserved, as compared with the following two experiments.

Experiment VIII (fig. 14).—Rabbit-eye. Autolysis for twenty-four hours at room temperature. No control preparation of this experiment was kept. Fixation in 50 per cent. alcohol. Stained by toluidin blue and Weigert's iron-hæmatoxylin.

The rods and cones had practically disappeared. The fibres of Müller in their outer segments were almost invisible, but were well marked in the region of the nerve-fibre layer. The external nuclei showed slight evidence of cross-striping. The external plexiform layer was more or less collapsed, but showed occasional "cog-wheel" markings. The chains of chromatin, forming the network in the bipolar cells, were broken up, and the spaces between them enlarged so that the cells often

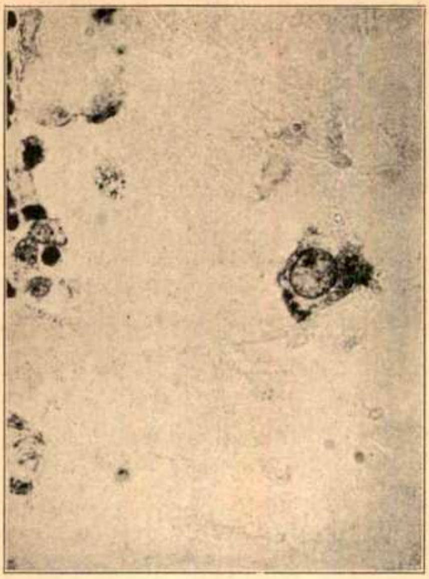


FIG. 14.—Rabbit-eye. Autolysis twenty-four hours (room temperature).

Tol. B. Photomic. × 1,000. Showing ghost-like ganglion cell with eroded edges. There is still evidence of the protoplasmic extensions. The nucleus is well preserved. Granular structure still visible in these cells.

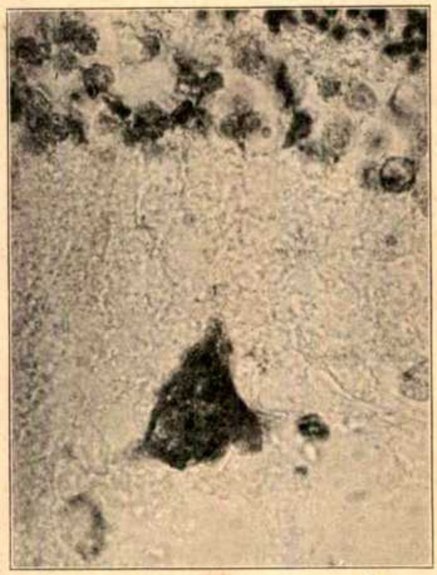


FIG. 15.—Rabbit-eye. Autolysis forty-five hours (room temperature).

Fixation in 50 per cent. alcohol. Tol. B. Photomic. × 1,000. Large ganglion cell with well-preserved processes. The nucleus is central and is in a state of good preservation. Nissl granules are present, but there is a tendency to diffuse staining. The cells of the inner nuclear layer are degenerated, but less so than those of the outer nuclear layer.

appeared devoid of contents. The ganglion cells were much eroded at the edges and were rarefied. Their nuclei were generally fairly well preserved, but the cell bodies were fragmentary. Nissl granules were almost completely absent.

Experiment IX (fig. 15).—Rabbit-eye. Autolysis for forty-five hours at room temperature. Fixation in 50 per cent. alcohol. Stained in toluidin blue.

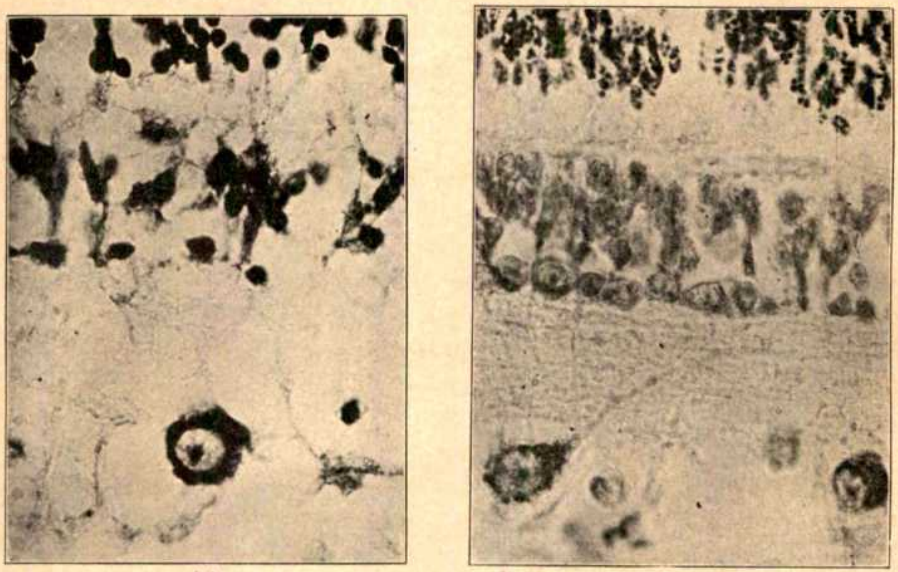
The retina had collapsed as a whole, and the portion available for examination was considerably reduced. The differentiation into layers at places was completely lost.

The nuclei of the external nuclear layer occasionally showed cross-striping, but there was no "cog-wheel" to indicate the network of chromatin. Müller's fibres were still more or less existent. There was a general tendency to diffuse staining in the cellular elements. The number of recognizable ganglion cells was small, their nuclei often being all that was left to mark their existence, and the cell body, if present, being much vacuolated. The processes were almost non-existent. The nerve-fibre layer was on the whole well preserved. Owing to the greater delicacy of the retina of the rabbit, the autolytic tissues were very liable to injury from histological manipulation. The finer gradations between the fresh condition and the more pronounced stages of autolysis were not demonstrable. As compared with the ox-eye, one observed that in the rabbit the fibres of Müller were more resistant, and the ganglion cells slightly less resistant.

Experiment X (fig. 16).—Kitten-eye. Autolysis for forty-eight hours at room temperature. Fixation in 50 per cent. alcohol. Stained by toluidin blue and by hæmalum and eosin. (This animal had been anæsthetized for several hours and the eyes were obtained about an hour after death.)

In the control we found that the rods and cones showed a slight fusion of their outer extremities. The nuclei of the external nuclear layer were arranged in many tiers (from four to six), the nuclei being elongated and rather densely stained. The chromatin network was very well demonstrated ("cog-wheel" and "cross-striping"). The internal nuclei were full of chromatin arranged in a fine network. The ganglion cells showed discrete well-stained Nissl granules arranged in concentric lines around the nucleus. The nucleolus was small and deeply stained. The processes of the ganglion cells were often very conspicuous. The blood capillaries were seen passing along the inner border of the outer plexiform layer, their endothelial nuclei being sometimes difficult to distinguish from those of the horizontal cells of the internal nuclear layer.

In the autolytic retina there was considerable collapse of all the elements. The rods and cones were no longer visible. The nuclei of the external nuclear layer were represented by small, circular, densely stained masses of chromatin with almost complete loss of detail. The nuclei of the internal nuclear layer were devoid of cell body and showed only slight evidence of a chromatin nuclear network. The nuclei of Müller's fibres were often densely stained. The ganglion cells had as a rule, rounded outer margins and eroded inner margins. The protoplasm of the cell body had a "stippled" appearance. Nissl granules, when present, were blurred in outline. The nuclei of the ganglion cells often appeared practically normal, except for some wrinkling of the nuclear membrane. There was not much vacuolation in any of the cells. Certain cells appeared almost normal except for a slight loss in sharpness of detail.



(*a*) (*b*)

Fig. 16.—Kitten-eye. Autolysis forty-eight hours (room temperature).

(*a*) *Autolytic eye.* Fixation in 50 per cent. alcohol. Tol. B. Photomic. × 1,000. Large ganglion cell with densely stained but still granular protoplasm. The nucleus is well preserved. The cells of the outer and inner nuclear layers are almost completely degenerated.

(*b*) *Control of* (*a*). Note the large typical ganglion cell with up-going process. The cells of the outer and inner nuclear layers present marked contrast to those of (*a*). Note the elongated rod nuclei with several horizontal interspaces between the chromatin masses.

Experiment XI.—Kitten-eye. Autolysis for ninety hours at room temperature. Fixation in 50 per cent. alcohol. Stained in toluidin blue, and hæmalum and eosin. (This animal had been the subject of a prolonged metabolic experiment.)

Control.—Hæmalum and eosin. The rods and cones were somewhat disorganized, and the external nuclei were densely stained, showing little internal detail, although a "cross-striping" was present.

The internal nuclei showed fair chromatin network in the hæmalum and eosin specimens. The ganglion cells showed vacuolation (fat-globules?) in many of the cells, even where there were typical appearances of Nissl granules and absence of diffuse staining. The edges of the cells, however, were often ragged and the processes were short. The small type of ganglion cell with eccentric nucleus and scanty protoplasm generally showed well-stained Nissl granules, although there was often a "washed-out" appearance of the chromatin which indicated that the cells were in a more or less abnormal condition.

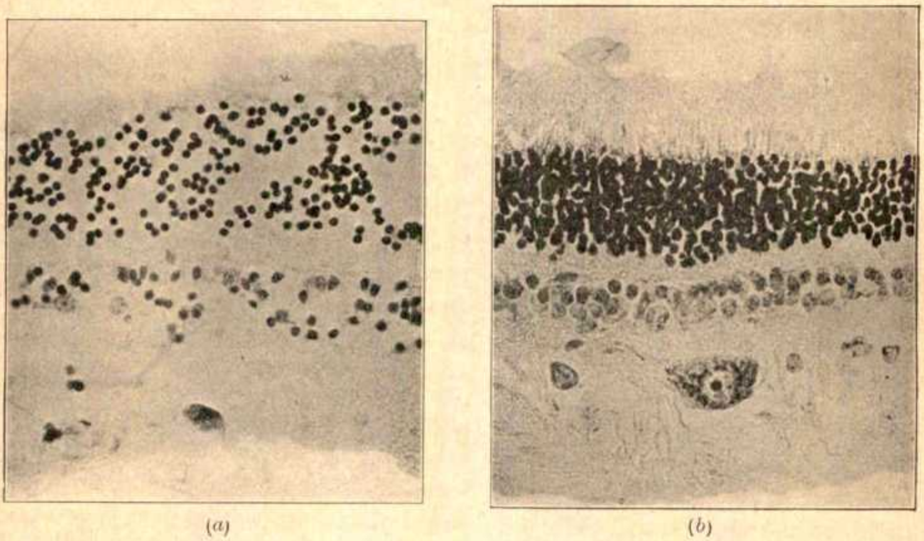
In the *autolytic* eye the appearances were very different. The rods and cones were invisible as such, and the various layers of the retina had become fused. The external and internal nuclei under low power view were not to be distinguished from one another, both being represented by small, shrunken, densely stained spheres. Higher magnification did not reveal any differentiation of the chromatin into a network. No Müller's fibres were to be found, and the nuclei of these fibres were indistinguishable from the others of the internal nuclear layer. The ganglion cells were much reduced in number. When present they were seen as large, somewhat spherical, isolated cells, having a very finely granular, densely stained nucleus. The processes had disappeared. In some cells the inner margin had eroded (as in the ox-eye). Fat-globules occurred frequently, and Nissl granules were generally absent. The nearest approach to the normal consisted in a very finely granular condition of the cell protoplasm, with faintly outlined dendritic processes.

The preservation in this retina was on the whole much the same as that of the ox-eye for the same period of autolysis (Experiment VI).

Experiment XII (fig. 17).—Dog-eye. Autolysis for forty-six hours at room temperature. Fixation in 50 per cent alcohol. Stained by toluidin blue, thionin, and hæmalum and eosin.

Control.—The preparations stained by thionin showed fairly well defined Nissl granules, but there was slightly more staining of the ground substance than was the case in toluidin blue. In the latter the granules stood out sharply defined against the colourless background. The protoplasmic processes of the ganglion cells were well differentiated in all the preparations. The nucleus was somewhat more densely stained by thionin than by toluidin blue. Vacuolation was, as a rule, absent. The blood capillaries were conspicuous as they crossed the internal nuclear layer to reach the external nuclear layer.

In the *autolytic* eye the rods and cones had become completely granular and unrecognizable as a palisade structure. The nuclear layers had become almost fused, the outer plexiform layer being greatly reduced in breadth. The external nuclei were densely stained and exhibited practically no structural detail (no "cog-wheel" or "cross-striping"). The "centrifugal" cells of the internal nuclear layer were fairly well preserved and showed considerable nuclear detail. The "horizontal" cells also were to be recognized. The ganglion cells showed erosion of the edges of the largest cells. The differentiation of the chromatin into granules was lost, the ground substance being



(*a*) (*b*)

Fig. 17.—Dog-eye. Autolysis forty-six hours (room temperature).

(*a*) *Autolytic eye.* Fixation in 50 per cent. alcohol. Tol. B. Photomic. × 500. Showing degenerated cells of the outer and inner nuclear layers. These layers are still separated from each other by the outer plexiform layer. The large ganglion cell below shows erosion of the inner edges and diffuse staining of the protoplasm. Granular structure still recognizable.

(*b*) *Control of* (*a*). Note the large typical ganglion cell with well-marked Nissl granules, central nucleus, and up-going process. The cells of the outer and inner nuclear layers are well differentiated.

diffusely stained. The nuclei were often diffusely stained and lacking in detail. There was vacuolation, especially in the medium-sized cells. The cell processes were sometimes well preserved and stood out against the degenerated supporting elements.

On the whole, however, the ganglion cells in this specimen were well preserved, in many the presence of fairly typical Nissl granules being demonstrable. Erosion of the cells apparently began on the inner aspect, *i.e.*, at the side towards the axis-cylinder, although the nerve-fibres themselves were comparatively resistant. It was the epithelial-like elements of the retina (rods and cones) which perished early, the more strictly nervous structures (nerve-fibres, ganglion cells) being preserved for a considerable time. The delicate terminals, however, of the external plexiform layer early succumbed, allowing of fusion of the nuclear layers.

The principal points to be noted in these experiments are erosion of the margin of the ganglion cell with diffuse staining of the protoplasm, absence of definite Nissl granules and degenerative changes in the nuclei. Shrivelling of the cells took place, and was probably the ultimate fate of all the cells, but one was struck with the absence of marked shrinking of the cells, when compared with the results of Birch-Hirschfeld and others, whose experiments were concerned frequently with a shorter period of *post-mortem* degeneration.

(*iii*) *Discussion of Results.*

It is evident from the foregoing description that the appearances in the retina which are associated with *post-mortem* changes are very different from those which occur as the result of operation during life. We have seen that the ganglion cells which, in the case of section of their axons, readily tend to degenerate, are comparatively resistant to *post-mortem* changes, cells which show tolerably good preservation being found at a period of ninety hours after death (in the case of the ox-eye), forty-six hours (in the case of the dog), and forty-five hours (in the case of the rabbit). In the outer layers, however, we find degeneration setting in with considerable rapidity in the direction of from without inwards. The rods and cones are the first of all the elements to degenerate, disappearing in the case of the ox before sixteen hours, and in the rabbit before eighteen hours, but in the dog only partially at forty-six hours. The nuclei of the rods and cones begin to show degenerative changes about the same time, and the nuclei of the inner nuclear layer somewhat later.

In the experiments described, the shorter periods given for each animal are those at or about which the first definite changes were made out. For example, in the case of the ox, where the changes for sixteen hours are defined, it is to be understood that changes may occur at a period less than that, but they are so slight and show so little progression that one has not placed undue importance on their recurrence. The lapse of several hours seemed to produce little effect on the cells when the eye was sealed from the atmosphere, and one's object was not so much to set a time limit upon the onset of changes as to investigate their sequence in the various layers. In the case of the rabbit retina it is true that changes set in before eighteen hours, but they are not pronounced, and one selected the periods at which definite changes are to be observed.

In the series described by Birch-Hirschfeld, changes are met with in all the elements as early as two hours after death, ending in complete destruction at eighteen hours. The difference between such results and those of the present series in which well-preserved ganglion cells are met with at a period of forty-five hours is probably accounted for by the fact that in the former case *putrefaction* was not excluded as a causal factor, whereas in the latter the possibility of its occurrence was reduced to a minimum.

PART III.—CONCLUSIONS.

(1) The range of variability amongst the so-called normal ganglion cells of the retina is considerable, and the differences are so great as to lead to the conclusion that the features described under the term *chromatolysis* are not necessarily pathological.

(2) The smaller ganglion cells of the retina seem to be specially liable to changes, and atypical cells are prevalent in the control experiments. They are to be discarded in the present investigation. The large multipolar cell, which in the healthy retina is of most frequent occurrence, appears recognizable as a type. This cell contains a central nucleus with one or more nucleoli, and shows, when treated by the alcohol-toluidin blue method, sharply defined Nissl granules of different sizes arranged more or less concentrically around the nucleus, the ground substance being quite colourless. Departure from this type to any marked extent may be taken to indicate abnormal changes.

(3) It is the absence of truly normal cells in any retina, rather than the occurrence of isolated abnormal cells that indicates a pathological

condition. When the number of normal cells is *nil*, and that of abnormal cells is excessive, degeneration is fairly established.

(4) The gradual sequence of chromolytic change (swelling of the cell body, eccentric position of the nucleus, diffuse staining of the protoplasm, vacuolation, &c.) is not demonstrated by the retinal ganglion cells. One is not always able to demonstrate the changes between the first trace of degeneration, in a cell (loss of definition in the Nissl granule), and complete atrophy. Almost normal cells may be found side by side with others in which there is diffuse staining of the protoplasm and nucleus, or others in which the cell is pale and contains small dust-like particles. Degeneration of any cell is indicated by the early loss of definition in Nissl granules and by the final or atrophic stage of the cell-process. Vacuolation is met with in the control with at least as much frequency as in the operated eye and probably does not represent the existence of a pathological condition during life.

(5) As a result of section of the optic nerve, the fibres of which constitute the axons of the ganglion cells of the retina, degeneration of the ganglion cells sets in as early as forty-eight hours after operation. Degeneration advances with the lapse of time, is pronounced at three weeks, and is complete at thirty-eight weeks, where all the cells are atrophic. The ganglion cells are the central sensory neurones of the retina, and are seen thus to perish upon section of their central processes.

(6) Practically no change takes place in the cells of the outer and inner nuclear layers, *i.e.*, in the more peripherally situated neurones existing in contiguity with the ganglion cells. They are therefore seen to remain unchanged when their connexion with the central neurones is severed. As peripheral neurones they are thus seen to have an independent existence.

(7) The fact that these peripheral retinal neurones have no special power of resistance is illustrated by the series of autolytic experiments in which degeneration was seen to occur in the reverse order from that of the optic nerve section experiments. The layer of rods and cones with their nuclei degenerate first, the inner nuclei being next to perish, the ganglion cells being comparatively resistant.

In conclusion, I wish to record my sense of great indebtednesss to Professor D. Noël Paton, under whose constant supervision this work has been carried out; also to Dr. G. Herbert Clark of this Laboratory for assistance in the operations.

The photomicrographs were taken by Mr. Richard Muir, Edinburgh. The camera lucida drawings are my own work.

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PLATE I.

Experiment II. Forty-eight hours after section of the optic nerve.

(1) *Operated.* Tol. B. Drawing (c.l.), o.i. $\frac{1}{12}$. Ganglion cells selected from different fields to show the best preservation. Note diffuse staining in most of the cells. The cells are smaller than in (2).

(2) *Control.* Tol. B. Drawing (c.l.), o.i. $\frac{1}{12}$. Different types of ganglion cells which occur normally. (*a*) is a so-called "normal" cell; (*b*) is a rarefied or "ghost" cell; (*c*) shows the nucleus eccentric.

Experiment V. Four days after section of the optic nerve.

(3) *Operated.* Tol. B. Drawing (c.l.), o.i. $\frac{1}{12}$. Showing ganglion cells from different fields. Most of the cells are small and stain feebly. The chromatin granules are dust-like. No quite normal cells appear (compare control).

(4) *Control.* Tol. B. Drawing (c.l.), o.i. $\frac{1}{12}$. Ganglion cells from different fields. (*a*) normal" cell; (*b*) small cell with eccentric nucleus and peripherally situated granules.

Experiment VII. Eight days after section of the optic nerve.

(5) *Operated.* Tol. B. Drawing (c.l.), o.i. $\frac{1}{12}$. Ganglion cells selected from different fields. Note pale staining and dust-like condition of the Nissl granules.

(6) *Control* as in (5) ganglion cells from different fields illustrating various types of cell, some of which are not "normal." Normal cells are frequent in the sections, however.

Experiment IX. Three weeks after section of the optic nerve.

(7) *Operated.* Fixation 50 per cent. alcohol. Tol. B. Drawing (c.l.), o.i. $\frac{1}{12}$. Showing small diffusely stained ganglion cells. The larger cells seen to the left show a dust-like condition of the chromatin.

(8) *Control* as in (7). Showing sharply defined Nissl granules in the ganglion cells.

(9) *Operated.* Fixation in $HgCl_2$. Tol. B. Drawing (c.l.), o.i. $\frac{1}{12}$. Ganglion cells from different fields. The cells are smaller than in control and have greater tendency to diffuse staining. No "normal" cells are to be found.

PLATE II.

(10) *Control* as in (9). Ganglion cells from different fields. These cells illustrate the atypical cells often met with in the controls.

(11) *Operated.* Fixation in formol saline. Tol. B. Drawing (c.l.), o.i. $\frac{1}{12}$. Ganglion cells showing somewhat diffuse staining. Vacuoles are frequent. The cells are smaller than in (12).

(12) *Control* as in (11). Ganglion cells showing large Nissl granules. Vacuoles are met with.

Experiment X. Six weeks after section of the optic nerve.

(13) *Operated.* Tol. B. Drawing (c.l.), o.i. $\frac{1}{12}$. Note the much diminished ganglion cells as compared with control. Staining is diffuse or there is a dust-like condition of the granules. (*a*) represents the nearest approach to a "normal" cell.

(14) *Control* as in (13). Note large typical ganglion cells (*a*) and (*b*), with atypical forms (*c*) and (*d*).

Experiment XI. Fifteen weeks after section of the optic nerve.

(15) *Operated.* Fixation in formol saline. Tol. B. Drawing (c.l.), o.i. $\frac{1}{12}$. Showing ganglion cells much diminished in size. Diffuse intense staining is the rule. There is no vacuolation. Pericellular spaces not enlarged. No normal cells are to be found.

(16) *Control* as in (15). Ganglion cells from different fields. Note vacuolation in (*a*), enlarged pericellular space in (*b*).

(17) *Operated.* Fixation in 50 per cent. alcohol. Tol. B. Drawing (c.l.), o.i. $\frac{1}{12}$. Ganglion cells from different fields. Note small size of cells, diffuse staining and absence of vacuolation. Pericellular spaces occasionally seen (*a*).

(18) *Control* as in (17). Showing many normal ganglion cells (*a*), with others (*b*) less typical.

(19) *Operated.* Fixation in $HgCl_2$. Tol. B. Drawing (c.l.), o.i. $\frac{1}{12}$. Showing differentiation even less well marked than in (17).

(20) *Control* as in (19). Differentiation less pronounced than in (19).

Experiment XII. Sixteen and a half weeks after section of the optic nerve.

(21) *Operated.* Tol. B. Drawing (c.l.), o.i. $\frac{1}{12}$. Ganglion cells much diminished in size. The chromatin, when granular, is lightly stained and is in the form of fine dust-like particles. Usually, however, there is a condition of dense diffuse staining of the protoplasm.

PLATE III.

(22) *Control* as in (21). Ganglion cells show large well-defined Nissl granules. A few rarefied cells may be seen (*a*).

Experiment XIII. Thirty-eight weeks after section of the optic nerve.

(23) *Operated.* Fixation in $HgCl_2$. Tol. B. Drawing (c.l.), o.i. $\frac{1}{12}$. Ganglion cells from different fields. Note the small size and absence of well-defined Nissl granules. There is wrinkling of the nuclear membrane; pericellular spaces are not enlarged.

(24) *Control* as in (23). Shows various types of ganglion cell. In (*a*) there is diffuse staining. Note presence of large cells with well-defined Nissl granules, a type never found in (23).

(25) *Operated.* Fixation in formol saline. Tol. B. Drawing (c.l.), o.i. $\frac{1}{12}$. Illustrates the condition of atrophy in the ganglion cells. Note shrunken cells and lack of vacuolation. Pericellular spaces not enlarged. Diffuse staining is prevalent, practically no granular structure being indicated.

(26) *Control* as in (25). Ganglion cells from different fields, showing large well-defined granules. Note vacuoles and conspicuous pericellular spaces.

Ox-eye, autolysis twenty-four hours (room temperature).

(27) *Autolytic eye.* Tol. B. Drawing (c.l.), o.i. $\frac{1}{12}$. Ganglion cells selected from different fields. Note their well-preserved condition. The processes are often conspicuous. Granular structure is well marked. There is occasionally a tendency to pale staining and vacuolation.

(28) *Autolytic eye.* Tol. B. Drawing (c.l.), o.i. $\frac{1}{12}$. Ganglion cells selected from different fields. The smaller cells show rather diffuse staining. The larger cells are somewhat ghost-like.

(29) Same as (28).

(30) *Control.* Tol. B. Drawing (c.l.), o.i. $\frac{1}{12}$. Showing different types of normal cells. (*a*) rarefied cell with eccentric nucleus; (*b*) cell containing discrete Nissl granules and eccentric nucleus; (*c*) cell which is profusely vacuolated; (*d*) small cell diffusely stained.

PLATE IV.

Ox-eye. Autolysis ninety-hours (room temperature).

(31) *Autolytic eye.* Tol. B. Drawing (c.l.), o.i. $\frac{1}{12}$. Ganglion cells from different fields. Staining is somewhat diffuse and often intense. The cell margins are eroded. Protoplasmic processes generally wanting. There is still indication of granular structure.

Kitten's eye. Autolysis forty-eight hours (room temperature).

(32) *Autolytic eye.* Fixation in 50 per cent. alcohol. Drawing (c.l.), o.i., $\frac{1}{12}$. Ganglion cells from different fields. Note the well-preserved cell processes; in (*a*) the stain tends to be diffuse.

(33) *Control of* (32), showing ganglion cells from different fields. (*a*) typical cell; (*b*) rarefied or ghost-like cell; (*c*) cell with tendency to diffuse staining of the protaplasm.

Dog's eye. Autolysis forty-six hours (room temperature).

(34) *Autolytic eye.* Tol. B. Drawing (c.l.), o.i. $\frac{1}{12}$. Ganglion cells from different fields. In (*a*) there is profuse vacuolation, and the cell-margins are eroded; (*b*) cell with well-defined process; (*c*) almost normal cell, showing tendency to diffuseness of stain.

(35) *Control of* (34). Ganglion cells from different fields. (*a*) typical cell with well-defined Nissl granules, central nucleus, and well-marked process; (*b*) somewhat rarefied cell, with eroded margins.

TOXIC DEGENERATION OF LOWER MOTOR NEURONE CELLS COMMENCING DURING INTRA-UTERINE LIFE IN AN INFANT DYING AT 2½ MONTHS.

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THE following case is worthy of being placed on record, because it is a rare example of atrophic paralysis noticed in a child at birth, and contributing to its early death at the age of 2½ months.

C. D. was born on September 30, 1909. Delivery took place at full term and was normal in every respect. The father and mother were said to be healthy and the patient was the last of eleven children, the eldest of whom was 17 years of age. There had been one miscarriage in connexion with the first pregnancy, the second child was premature and only lived a few days, and another child died in convulsions at 9 weeks; in other respects the children were healthy. The mother stated that this child had never moved her legs since birth and that she had not moved her arms since she was three days old. She had never been able to move her head.

On November 26 the mother noticed the child was very thin about her chest and arms and took her to Guy's Hospital, where she continued to attend as an out-patient until December 17. The child had never been able to cough or to cry.

On December 17 the child was admitted to the Belgrave Hospital for Children under my care and I saw her at 9.45 p.m. She was pale and cold, with feeble pulse and subnormal temperature. She was fairly well nourished and had taken food satisfactorily until two days before admission. The bowels had acted naturally.

On examination I found her breathing rapidly, about 60 times a minute, and her pulse going at the rate of 150 beats per minute. The respiration was being carried on entirely by the diaphragm, which appeared to be acting vigorously. There was no sign of any intercostal movement, in fact the costal cartilages were drawn in on both sides of the sternum, from the first downwards, with the result that there was a remarkable degree of pigeon-breast. The accessory muscles of respiration were not employed, and there was slight recession of the intercostal spaces. The most striking feature in the child's appearance was the general flabbiness and lack of "back-bone." The face was expressionless, the mouth hung open and the head fell loosely in response to gravity without any attempt at support on the part of the neck muscles. With the exception of the diaphragm and the extensors and flexors of the fingers, all the muscles of the trunk and arms appeared to be completely paralysed. The fingers were sustained in the claw position and there were occasional spontaneous movements of the fingers, generally in the direction of flexion.

The legs were also flaccid and never moved spontaneously. The stimulation of the soles of the feet gave rise to faint flexion of the ankles and of the knees. The eye movements appeared normal and I have no doubt that she both saw and heard. Swallowing was performed naturally but slowly. It was impossible to form any opinion about her sensibility to pain or touch. The abdominal reflexes were not obtained. No tendon-jerks were elicited and I could obtain no contraction of any muscles on direct percussion. The lungs were resonant all over, but scattered râles could be heard in many places. Examination of the heart revealed no definite disease.

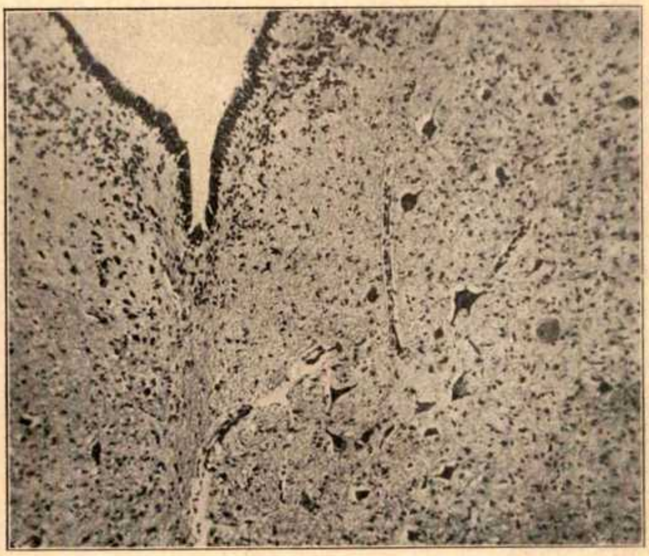

FIG. 1.—This photograph gives a general view of the hypoglossal nucleus and shows the scarcity of normal cells of good size and shape, as well as one or two which are undergoing chromatolysis.

The child died suddenly at 10.30 p.m.

Post-mortem, sixteen hours after death: Rigor mortis of a kind was present, that is to say, the whole of the soft tissues seemed to consist of a thick putty which could be easily moulded by the fingers and which bore the mark of every pressure.

Dense pale subcutaneous fat was abundant everywhere. The muscles were generally small but natural in colour.

The brain and spinal cord were natural in appearance at first sight. On closer examination the anterior roots of the cord and the lower cranial nerves, *i.e.*, seventh, tenth, eleventh and twelfth, looked small and fragile and were difficult to detect. The posterior roots and the third, fifth, sixth, and eighth nerves appeared to be of normal size and well myelinated compared to the others.

There was a large thymus reaching down to the diaphragm on the right side and nearly as far on the left, and attached above to the vessels behind the top of the sternum. It was natural in appearance.

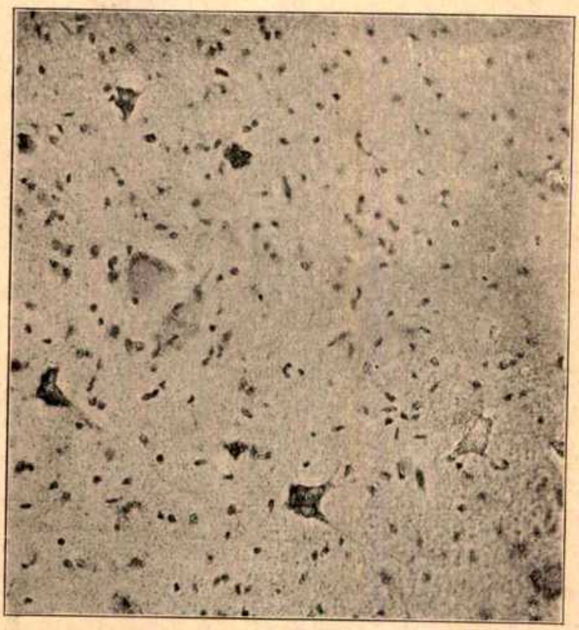

FIG. 2.—Cells of the hypoglossal nucleus, two of which are fairly healthy but poorly differentiated. Two others are of the "ghost" variety.

The thyroid gland looked natural. Below the thyroid on either side of the trachea were two or three large glands (? parathyroids). There were no signs of pressure on the trachea anywhere. The lungs were covered with petechial hæmorrhages and there was bronchitis and some basal congestion. Heart normal. Liver and spleen and kidneys normal. Well-developed suprarenals. Mesenteric glands large but not obviously diseased. Lymphatic elements in intestinal wall not conspicuous.

The nerves were natural in appearance. Portions of the ulnar, radial, median and sciatic were kept. Muscles were taken from the neck, back and front, diaphragm, front of forearm and hamstring region.

MICROSCOPICAL EXAMINATION.

Central nervous system.—Parts of the cerebral cortex, mesencephalon, medulla and spinal cord were examined by the Nissl method, the Weigert-Pal method, by the Marchi method, and by the Van Gieson stain.

The cerebral cortex showed nothing abnormal. Sections through the oculo-motor nuclei were also free from obvious changes. Sections through the medulla showed marked changes in the cells of the hypoglossal nucleus. The number of cells was diminished and few of the cells which remained could be regarded as healthy. The majority were small and appeared to be generally atrophic; others presented swelling and marked chromatolysis. In the spinal cord the anterior grey matter at all levels showed similar changes in regard to the ganglion cells. The deficiency in number and the poor size and irregular shape of the survivors were noticeable everywhere. There were no signs of reaction

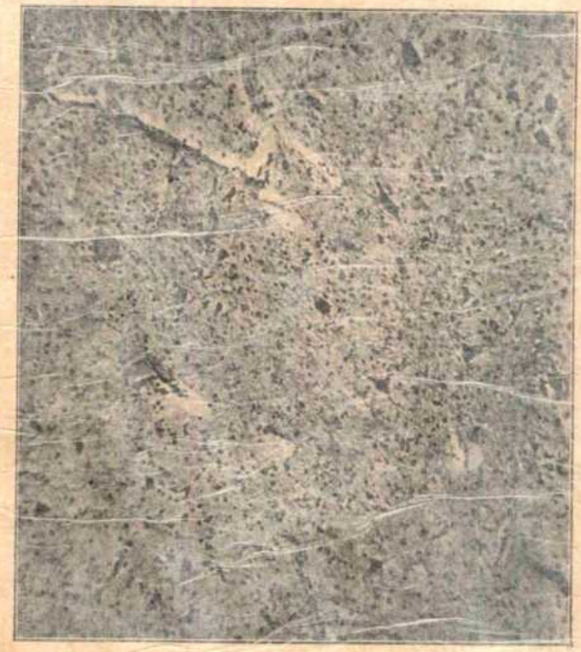

FIG. 3.—Anterior horn from the cervical region. Note the paucity of cells and their poor quality.

or inflammation in any part of the cord or brain-stem, and the vessels appeared to be perfectly healthy. Sections of the spinal cord stained by the Marchi method showed a few scattered degenerated fibres in the posterior columns at all levels, but no sign of degeneration in any other parts. In the Weigert-Pal sections the appearances were normal when the age of the child is taken into consideration.

Peripheral nerves.—The ulnar, radial, median and sciatic nerves were examined. By the Weigert-Pal method they appeared to be well myelinated. No interstitial changes were to be seen in sections stained by ordinary methods. By the Marchi method a very small number of fibres showed slight evidence of changes in the myelin sheaths, but these were insignificant as compared to the marked changes found in the anterior horn cells and in the muscles.

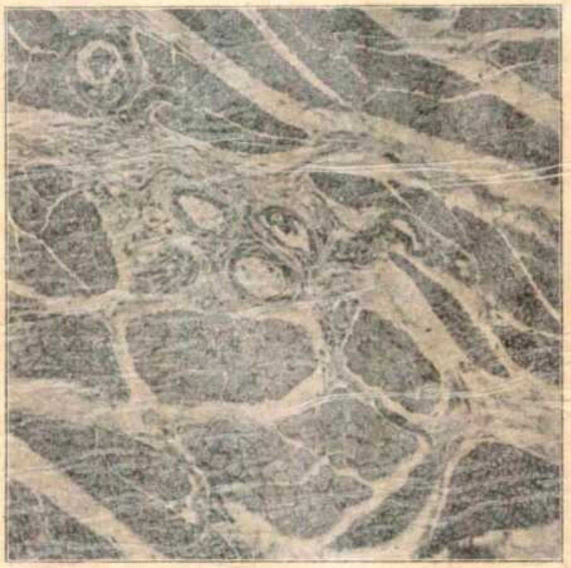

FIG. 4.—Transverse section of flexor muscle of forearm. Five bundles show a preponderance of fair-sized fibres; all the other bundles contain minute fibres.

Skeletal muscles.—All the muscles examined showed similar changes varying in intensity. Both in transverse and longitudinal sections great differences could be seen in the condition of various bundles of fibres. Some appeared to be normal in size and in other respects; others showed varying degrees of simple atrophy, or, what might be another interpretation, of imperfect development. It was characteristic of these muscles that individual bundles were affected rather than individual fibres, as will be seen in the accompanying photographs. There was no evidence of any interstitial change and the muscle-spindles presented a healthy appearance.

Other organs.—Microscopic examination of the heart, liver, spleen, suprarenals, thymus gland and mesenteric glands revealed no signs of disease.

A consideration of the clinical history and pathological examination of this unusual case leads to the conclusion that there must have been some toxic influence at work during the later period of intra-uterine life. It is justifiable to suppose that the poison affected chiefly the motor nuclei of the medulla and spinal cord, and so indirectly caused degeneration of the muscle-fibres throughout the body, or interfered with their natural development. It is tempting to suggest that the small atrophic cells of the anterior horns and hypoglossal nuclei represent those which failed to develop, while the swollen "ghost cells" represent the few which reached maturity, only to fall victims to the circulating toxin. Such a theory might help to explain the relative paucity of fibres in the peripheral nerves, which were shown to be undergoing degenerative changes.

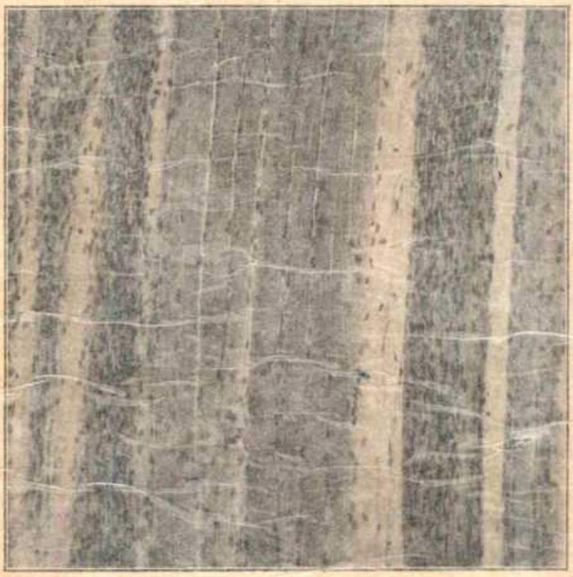

FIG. 5.—Longitudinal section from the same muscle.

It is difficult to believe that any myopathic disease could be the primary morbid process in view of the changes found after death.

PATHOLOGICAL EXAMINATION OF THE FRESHLY FIXED EYES FROM A CASE OF AMAUROTIC FAMILY IDIOCY.

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IN a case of amaurotic family idiocy recently reported in BRAIN (J. F. Poynton, J. H. Parsons, and G. Holmes [6]) the pathological examination of the eyes was admittedly incomplete, as they were only obtained thirty hours after death, and had suffered much from *post-mortem* change. The following case, in which the eyes were excised immediately after death and in which fixation left nothing to be desired, may serve to supply some missing details. For the notes of the patient's condition during her residence in hospital, and for the trouble taken to obtain the eyes, we are deeply indebted to Mr. Hildred Carlyll, Resident Medical Officer to the East London Hospital for Children.

CLINICAL NOTES.

The patient, Jenny M., was the child of Russian Jews who were not related. She was the youngest of five children, of whom the first and third died in infancy, not of this disease; the second is now 8 years old and well; the fourth was an amaurotic idiot, and died at the East London Hospital for Children. This case was reported by Dr. F. W. Mott [8].

The present patient was brought to the hospital first when one month old, and again two months later, because the mother thought she was not observant. At the second visit the fundi were found to show the typical picture of amaurotic family idiocy, with partial optic atrophy. The patient was a full-time child; she was breast-fed for eleven months, and when 1¼ years of age was admitted as an in-patient.

On admission her weight was 1 st. 6 lb. She was fairly well nourished, ate and slept well, and cried less than other children. Heart and lungs normal. No convulsions. Limbs spastic. The eyes were kept open, but she took no notice of external objects; the pupils were dilated, but reacted sluggishly to a strong light. No nystagmus or strabismus.

For four or five months nasal feeding was employed, but the child gradually went downhill and became more stuporose. The limbs were more spastic, the head retracted, and she lay as she was placed without offering to move. The forearms were pronated, the wrists flexed, the thumbs much adducted, and claw hand was present. Knee-joints flexed, very great drop foot. Sores gradually developed at the site of contractures; and at death were present to an extreme degree, as was also the muscular wasting. Extensor plantar reflex on each side. The optic atrophy became complete. Latterly several attacks of bronchitis occurred, with pyrexia, but for the greater part temperature was normal. Death occurred when the child was a little over 2 years of age. Permission having been previously obtained, the eyes were immediately enucleated and fixed, one in Zenker's fluid, one in Müller. Further than this, no *post-mortem* examination was allowed.

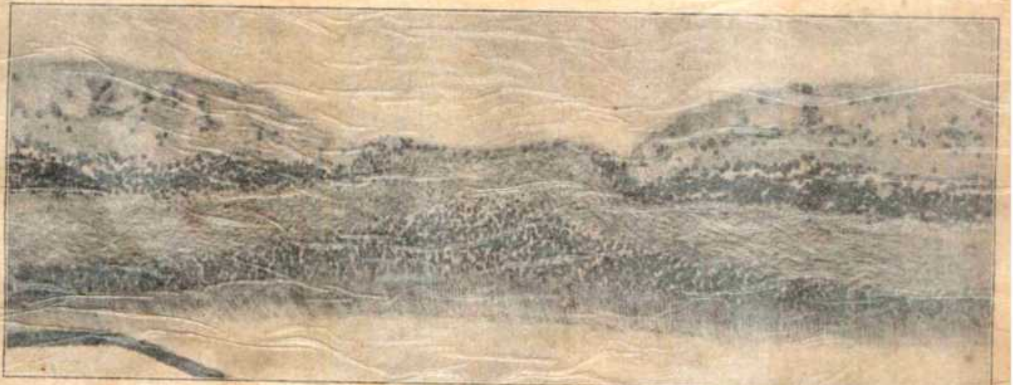

FIG. 1.

General view of the macula. The foveal pit is shallower than normal owing to thinning of the ganglion cell and nerve-fibre layers on each side. All the other layers are strictly normal. In the ganglion cell layer large, round, swollen-looking cells occur; they sometimes lie in spaces which they do not completely fill. Many of the small dark nuclei also belong to ganglion cells; some are neuroglial.

PATHOLOGICAL EXAMINATION.

Both eyes were divided horizontally immediately above the level of the macula. The halves containing the macula were embedded in celloidin, and a complete series was cut through that region, every section containing the foveal pit being mounted. Paraffin sections were made from the retina of the other half.

The stains used were hæmatoxylin and eosin, v. Lenhössek's modification of the Nissl method, and Mayou's modification of Pappenheim's stain [13], which proved excellent for the study of the nucleolus and of the finer changes in the nucleus and protoplasm. Giemsa's stain was also used, but, beyond defining the cell bodies, rendered no special service. The Müller-fixed eye was stained by the Weigert-Pal process.

Probably owing to the methods of fixation, Bielschowsky's method did not yield satisfactory staining. By far the best results were obtained from the Zenker-fixed eye, in which the histological preservation, as judged by the state of the rods and cones, was practically perfect.

MICROSCOPICAL EXAMINATION.

The changes are absolutely confined to the ganglion cells and their corresponding nerve-fibres. Owing to a certain diminution of these elements the foveal depression is shallower than normal; otherwise the general architecture of the macula is quite unchanged; there is no folding, œdema, or detachment, and the nuclear, reticular, and rod and cone layers are strictly normal (fig. 1).

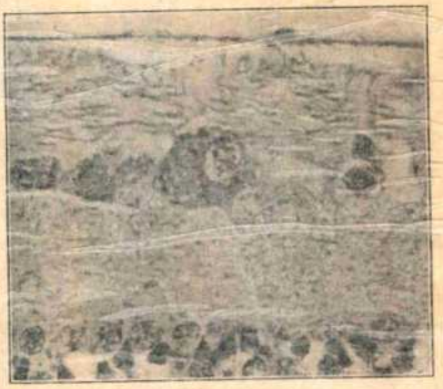

FIG. 2.

× 600. A normal ganglion cell, stained with Mayou's modification of Pappenheim's stain.

In reality, the loss of ganglion cells is not nearly so great as it seems, the appearance being due partly to the poor staining and inconspicuousness of the cell body, chiefly to the shrinkage of the nucleus; in the vicinity of the fovea, three to four layers of ganglion cells can usually be counted, the average in this situation being about five. Ganglion cells are found right out to the periphery of the retina, and in that situation seem to be, on the whole, less affected than in the macula. The ganglion cells which normally occur in the inner nuclear layer are also degenerate. The nerve-fibre layer is atrophied, but less completely so on the nasal than on the temporal side. The choroid beneath the macula and elsewhere is normal. The central vessels are normal, both in the nerve and in the retina.

The most striking change in the cell protoplasm is the total absence of Nissl granules. Not a single cell is to be found in which they are normal;

only exceptionally are they indicated at all by the presence of a rather coarsely granular material which takes on a purplish or violet tinge with thionin (fig. 4); for the most part all trace of them has disappeared.

In the cells which have undergone least change the normal cyto-reticulum is fairly well preserved, and the protoplasm is finely granular. Advancing degeneration is indicated by the appearance within the cell, usually near the nucleus, of a vacuole-like area filled with a perfectly homogeneous substance, the remains of the granular protoplasm being displaced to the periphery (figs. 3 and 4). With Mayou's modification of Pappenheim's stain this new

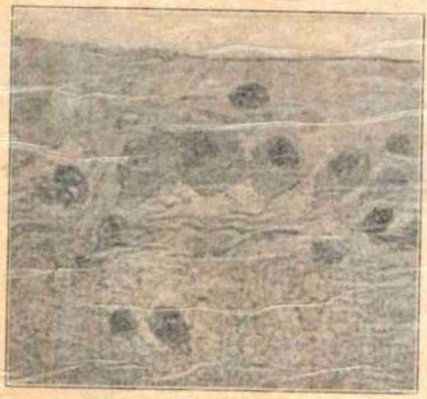

FIG. 3.

× 600. Ganglion cells from the present case, stained by the same method. The cells are round in shape, but not enlarged; the Nissl granules are lost. The protoplasm is finely granular, but one of the cells shows a large area in which it is homogeneous (and stained greenish). The nuclei are shrunken and crenated. The nucleolus is visible in the right hand cells.

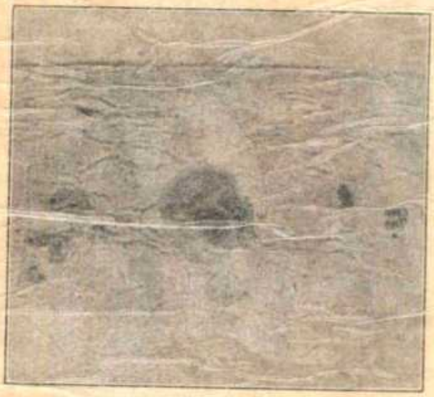

FIG. 4.

× 600. A ganglion cell, stained by v. Lenhössek's modification of the Nissl method. It is enlarged and filled with a granular material which stains purplish. This type of cell is very exceptional. All trace of the granules is usually lost.

substance takes on a light greenish tinge which is quite foreign to the normal cell; in hæmatoxylin-eosin specimens it is slightly bluish. These homogeneous areas increase at the expense of the normal cytoplasm, and finally may replace it entirely; it is rare to find more than one area in a single cell, but sometimes there are several separated by a network of granular protoplasm. True vacuoles, without contents, are not found.

Only exceptionally is a cell found with any indication of the normal cell processes; for the most part they have completely disappeared. In consequence the cells have a more or less rounded shape, and this, together with the homogeneous nature of their contents, and the shrinkage of the nucleus, gives them a swollen, bloated appearance. Comparison with normal ganglion cells shows, however, that though there is considerable variation, the average size of the cells is, if anything, below rather than above the normal. True swelling is almost confined to the vicinity of the fovea, where some of the cells are greatly enlarged, have a perfectly homogeneous protoplasm, and lie within spaces which they do not completely fill (fig. 1).

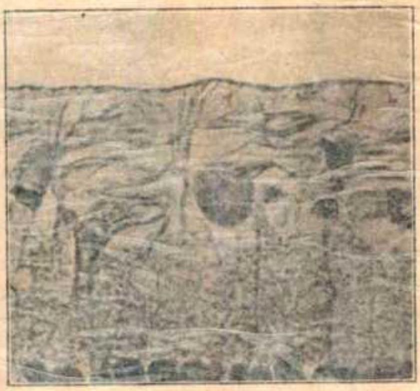

FIG. 5.

× 600. A ganglion cell stained with hæmatoxylin and eosin. It shows the rounded form, the eccentric nucleus, and the formation of a vacuole-like homogeneous area in the protoplasm.

Normal nuclei are scarcely to be found. The characteristic change is a shrinkage whereby the outline becomes crenated and the chromatin reticulum condensed. In the more degenerate cells the reticulum becomes indistinct, the nucleus being filled with irregularly disposed granules of varying degrees of coarseness. The ordinary nuclear stains are consequently taken on very darkly and diffusely. The nucleus is always eccentric, but this is its normal position in the retinal ganglion cells: it frequently projects on the surface, and sometimes a crescentic shrunken nucleus seems to form a sort of cap outside the contour of a balloon-shaped cell. The nucleolus is preserved up to an advanced stage of degeneration. Cells without a nucleus are found, but the appearance is probably due to peripheral cutting. The occurrence of nuclei not surrounded by protoplasm is probably due to the breaking up of the cell; such nuclei are not always easily distinguished from those of the neuroglia, which are perhaps increased in number, but whereas the neuroglial nuclei are plump and show the normal reticulum, the others show the characteristic changes already described.

In the nasal half of the optic nerve a few broken-up and varicose nerve-sheaths are still stainable by the Weigert-Pal process. In hæmatoxylin-eosin specimens the nerve appears to be unduly cellular, perhaps from increase of neuroglia; the increase of cells is confined to the nervous substance, and does not affect the trabeculæ.

The above description sufficiently establishes the identity of the changes in the ganglion cells of the retina and of the central nervous system. This identity was first proved by Holden. The only notable point in which we differ from the excellent account of the changes in the central nervous system recently published in this periodical [6] is this, that whereas in that paper the nucleus is described as being usually "about normal" in size, in the present case it was almost invariably shrunken. We regret that the failure of Bielschowsky's method prevented us from studying the neuro-fibrils.

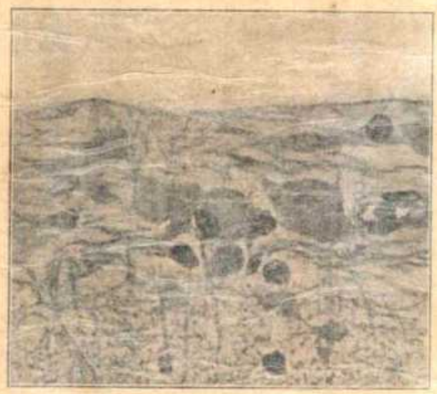

FIG. 6.

× 600. Ganglion cells stained with hæmatoxylin and eosin. In the cell on the right the nucleus is much shrunken, in that on the left it projects beyond the cell body.

Our results are also essentially the same as those of other recent authors who have obtained the eyes sufficiently soon after death to be of much value.[1] From a study of these cases it may now be stated with certainty that folds and detachments at the macula, œdema of the retina, holes in the fovea, and thickenings of the reticular and nuclear layers are artefacts; and due to imperfect fixation or *post-mortem* change. A hole in the fovea has been observed by one of us as a *post-mortem* change quite apart from amaurotic family idiocy.

---

[1] M. Cohen and G. S. Dixon. Eyes obtained two and a half hours *post-mortem*. F. H. Verhoeff: Eyes obtained fifteen minutes after death. In Mott's second case the eyes were excised immediately after death, but no pathological examination of them seems to have been recorded. According to Birch-Hirschfeld [7] the retinal ganglion cells begin to show *post-mortem* changes in two hours and their characteristic structure is lost in about seven hours.

The proof that a change in the protoplasm of the ganglion cells is capable of causing the ophthalmoscopic appearance of retinal opacity with a foveal cherry-red spot is of interest in connexion with the subject of obstruction of the central artery of the retina, and lends support to Elschnig's contention that the similar ophthalmoscopic changes in that condition are due not to œdema, but to a coagulation necrosis of the ganglion cell from the cutting off of their blood supply. The subject has been more fully discussed by us elsewhere (G. Coats [11]. W. I. Hancock [12]).

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[8] Mott, F. W. *Arch. of Neurology*, 1907, vol. iii., p. 218 (230).

[9] Verhoeff, F. H. *Arch. of Ophthal.*, 1909, vol. xxxviii, p. 107.

[10] Schuster, P. *Arch. f. Augenh.*, 1909, Bd. xlvi, S. 1.

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[11] Coats. *Roy. Ophth. Hosp. Reports*, 1905, vol. xvi, p. 293.

[12] Hancock. *Roy. Ophth. Hosp. Reports*, 1908, vol. xvii, p. 437.

[13] Mayou. *Trans. Ophth. Soc.*, 1904, vol. xxiv, p. 338.

Publications Recently Received.

[Notes on a book under this heading do not preclude a subsequent review.]

Ueber Geschwülste der hinteren Schädelgrube insbesondere des Kleinhirnbrückenwinkels. Von Dr. Folke Henschen. Mit 9 Tafeln. S. 283. Jena: Fischer, 1910.

The author has put together an account of twenty-eight cases of tumours in the posterior fossa of the skull. He divides them into a general group and tumours of the auditory nerve, which he calls tumours of the cerebellar angle, "par préférence." In the diagnosis, the most certain localizing signs are those due to affections of the cranial nerves, the trigeminal, the facial, or the auditory. Hearing should be investigated with unusual care, as the majority of the tumours in this region grow from the auditory nerve. Most of the cases discussed in the text are illustrated on the plates by drawings of the tumour *in situ.*

Eine eigenartige familiär-hereditäre Erkrankungsform (Aplasia axialis extracorticalis congenita). Von Privatdozent Dr. L. Merzbacher. Mit 40 Textfiguren. S. 138. Berlin: Springer, 1910.

In 1885 Pelizaeus described a curious family-disease of unknown cause. By a remarkable chance the brain of a member of this family came into the possession of the author, who was able to add ten cases to the four already described by Pelizaeus. The affected members of this family never walk, and show nystagmus and head-nodding from birth. The disease is transmitted by unaffected females, and twelve out of fourteen cases are males. Many become demented. The pathological change seems to be a destruction of the medulla of the nerve-fibres; axis cylinders are everywhere left naked in the central nervous system.

Konstitutionelle Verstimmung und Manischdepressives Irresein. Von Privatdozent Dr. Eduard Reiss. S. 282. Berlin: Springer. 1910.

The Swabians are known to be a quiet, somewhat brooding and melancholic race of the German people. The author, when assistant in the Tübingen Clinic, attempted to discover what effect this temperamental condition exerted on the functional psychoses, such as maniacal depressive insanity. He was able to observe 181 cases, and to see the patients after their cure. He came to the conclusion that temperamental depression in a people leads to a predominance of the melancholic forms amongst the insane. But during the course of these melancholias phases occur which bear little relation to temperament. The true circular insanities are quite uninfluenced by a constitutional tendency to depression. This is a most interesting study, and deserves attention from all those interested in the developments we owe to Kraepelin and his school.

Text-book of Nervous Diseases for Physicians and Students. By Professor OPPENHEIM, of Berlin. Fifth enlarged and improved edition, with 432 illustrations in the text, and 8 plates. Authorized translation by ALEXANDER BRUCE, M.D. F.R.C.P.E., Physician to the Royal Infirmary, Edinburgh. Vols. 1 and 2. Pp. 1424. Edinburgh: Otto Schultze, 1911.

This is a faithful rendering into English of the last edition of Professor Oppenheim's text-book. It is well printed, and will be useful to all who cannot read this standard work in the original language.

Mentally Deficient Children, their Treatment and Training. By G. E. SHUTTLEWORTH, M.D., and W. A. POTTS, M.D. Third edition. Pp. 236. London: Lewis, 1910.

This well-known work has been brought up to date with the help of Dr. Potts. The facts of defective mental development in children are clearly given, and clinical types are shortly described. In many cases the descriptions are illustrated with excellent photographs. No better book could be placed in the hands of a medical man interested in the many questions which arise from mental deficiency in children.

The Brain and the Voice in Speech and Song. By F. W. MOTT, M.D. F.R.S. Pp. 112. London and New York: Harper, 1910.

This little book is clearly written in simple language, and technical terms are avoided. Not only the physics and physiology of voice production, but the nature of the mechanisms of speech are explained. As might be expected, the information is completely up to date, and the book will be useful to teachers and students of music who want to obtain a correct elementary knowledge of the voice.

Writers of "Original Articles and Clinical Cases" are supplied free of charge with 50 copies reprinted in the form in which the paper stands in the pages of "Brain." If reprints are required in pamphlet form, with wrapper, title-page, &c., and re-numbered pages, they must be ordered, at the expense of the writers, from Messrs. BALE, SONS & DANIELSSON, Ltd., 83-91, Great Titchfield Street, London, W.

Members of the Neurological Section of the Royal Society of Medicine can obtain the Index of "Brain" for the Volumes I. to XXIII. inclusive, that is, from its commencement to the end of 1900, from Messrs. MACMILLAN & CO., Ltd., St. Martin's Street, London, W.C., at the price of 6s. 6d., post free.

To those who are not members of the Neurological Section of the Royal Society of Medicine the price is 8s. 6d. net, and the volume may be obtained through any bookseller.

EDITOR.

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A JOURNAL OF NEUROLOGY,

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